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Cement Industry-A Broad Overview

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Overview of Cement Industry

1.0 Introduction

The Indian Cement Industry - the third largest cement producer of the world, with an installed capacity of over 105 million tonnes per annum, is one of the basic industries and has been playing an important role in the economic and social developments of the country The industry has created a well deserved niche in the economic sphere and has more than redeemed faith and confidence of the public and policy makers in the government There has been a spectacular growth in cement production through state-of the art technology energy management systems and environment protection strategies - which are second to none in the world

Energy - fuel and power, is one of the major cost components in cement manufacture, and accounts for more than 45% share of the total production cost of cement in India In the last few years fuel and power consumption per tonne of cement have continued to register downward trend progressively over the years and same of the modern and recently commissioned plants have achieved excellent results which are comparable to the international bench marks Today there is a slogan in cement industry for achieving higher productivity, lower energy consumption and also improved environmental protection. Improved environmental research study indicates that average specific heat consumption level of dry process cement plants was 780 12 kcal/kg clinker in the year 1995-96 As regards to the electrical energy the specific power consumption level of the dry process plants was 104 35 kwh/tonne cement in the year 1995-96 The study also indicates that some 14 plants achieved the largest of consuming electrical power at 95 kwh/tonne cement One cement plant, as reported, broke all the previous records and achieved thermal (heat) consumptions of 680 kcal/kg clinker. The plant also achieved electrical (power) consumption landmark of 88 kwh/tonne of cement during a continuous plant run of three months The study report has identified factors and measures which have been implemented by engineers and scientists of the cement plants for achieving reduction in the energy consumption levels The engineering and consultancy firms, the cement research institutions and cement manufacturers association in one way or the other have substantially contributed in achieving the best and pragmatic results in energy consumption.

A new technological development being widely discussed in seminars workshops and training courses is cogeneration. Cement manufacturing process generates huge quantity of waste heat Cogeneration of power, utilizing this waste heat is not only technologically feasible but economically acceptable cogeneration of power can reduce strain on the economy because of reduction in the consumption of diesel oil in DG set which are increasingly being installed by cement plants to offset power shortage and frequent power cuts imposed by state Electricity Boards. Cogeneration schemes have not yet been implemented by Indian Cement Industry mainly due to lack of confidence level for its adoption and also lack of thrust and fiscal incentives from

Government, International aid agencies like GEF with an active support of UNDP are considering extending financial assistance for a pilot plant study on cogeneration of power utilising waste heat.

In summing up, despite the present recession in cement industry, the future of Indian cement industry, appears to be bright since the construction industry has to meet the aspirations of the Indian Society. Energy and Environment shall continue to be in focus in the years to come.

One of the challenging issue facing mankind at this juncture is that of pollution control and environmental protection, of the Mother Earth. The carrying capacity of air, water and land has far exceeded and is being threatened leading to a strain in the man-nature relationship. The ecological cycle comprising of energy, oxygen, nitrogen, carbon, water etc., is the loser in the short run, but mankind would be the ultimate loser. It is feared that in the decades to come, life in its present style will become increasingly unsustainable on the earth, due to ecological imbalance and degradation of the earth. Confirmed scientific studies warn that the depletion of ozone layer due to excessive generation of green-house gases, mainly the carbon-di-oxide emissions, shall lead to global warming resulting in the rise of sea-water levels in many parts of the world which might eventually physically submerge large land from the geographical map of the world.

Industrial activities are essential for improving living standards of the habitat. It is essential to ensure increased availability of goods and services that go to make living easier. Every industrial process has its own shortcomings but man can not live without goods and services produced by industry. This calls in for striking a balance between 'Nature' and 'Development'. The Stockholm conference held in 1972, highlighted the concept of sustainable development and the need for conservation of nature It also advocated a fresh look at resources utilization and warned of possible consequences of indiscriminate growth.

"The then Prime Minister of India, Smt. Indira Gandhi stated in the conference that" the environmental problems of developing countries are not the side-effects of industrialisation but reflect the inadequacy of development. The rich countries may look-upon development as the cause of environmental destructions, but to us it is one of the primary means of improving the environment for the living, or providing food, water, sanitation and shelter, or making the deserts green and the mountains habitable".

The Constitution of India, provides vide article 48A the "Directive Principles of State Policy" which stipulates that "the state shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country." Similarly Article 51 A(g) provides that "It shall be the duty of every citizen of India to protect and improve the natural environment

including forests, lakes, rivers and wild life, and to have compassion for living creatures".
Over the last 50 years since Independence, the Indian Parliament enacted comprehensive legislations in line with the Stockholm Conference Declarations of 1972 The most important being "The Environment Protections Act 1986", called an Umbrella Legislation. The Ministry of Environment & Forests (MOEF), and Central Pollution Control Board (CPCB) have been assigned the statutory responsibilities for the protection of environment. Cement Industry has been identified as one of the highly polluting industry by the MOEF & CPCB. The Central Pollution Control Board has fixed standards for ambient air quality as also emissions from stack The details are.

I. Ambient Air Quality Standards

No.	Area Category	SPM µg/m3	SO2 µg/m3	CO µg/m3	NOx µg/m3
1.	Industrial & Mixed	500	120	500	120
2.	Residential & Rural	200	80	200	80
3.	Sensitive	100	30	100	30

II. Emission Limits from Stack

	Plant Capacity TPD	Particulate matter Emissions not to exceed mg/Nm3 Protected Area	Other Area
a	< 200	250	400
b	> 200	150 115 (in AP)	250

The Indian Cement Industry, spread-over in 19 states, is aware of its social & moral responsibilities towards the nation It is constantly improving the manufacturing technologies and is all set to meet the stringent regulatory standards It is possible to design and install pollution control equipments to meet emissions standard of as low as 50 mg/Nm3. However, the existing cement plants with age old pollution control equipments face problems in achieving stringent

statutory norms, as they find difficulties in retrofitting new pollution control assemblies. Again, there is a trade-off between costs and benefits in to-day's competitive buyer's market.

Since cement industry is location specific, depending on availability of limestone, clusterisation of cement plants is inevitable. There are as many as seven cement producing clusters. Though individually, cement plants are well equipped with state-of-art technology for pollution control and meet stipulated regulations, the collective emissions and total emission load as ambient air quality of the region, needs regular air quality monitoring and implementation of abatement measures.

The Indian Cement has a very ambitious growth plan in the 21st century. To meet this challenge, what is required is a joint integrated and comprehensive efforts by all the existing & future cement plant/project entrepreneurs to design, retrofitt and operate their pollution control equipments These sincere efforts would go a long way in meeting the social obligation towards the community in the arena of environmental protection.

Plant Management in Cement Plant

Plant Maintenance Management in Cement Industry

1.0 Introduction

Cement Industries are energy and capital intensive. The cement manufacturing process also involves hazardous conditions and risk to plant, personnel and public. Proper Maintenance Management has been observed as one of the important elements towards overall improvement of the cement industry, specifically in terms of energy and environment effectiveness. It has been observed from performance parameters that maintenance productivity has direct relation to energy consumption and also environment performance. This article describes the latest developments in plant maintenance management that can play stellar role in energy and environment management of Cement Industries.

2.0 Role of maintenance in energy conservation & environment preservation

Conservation of energy and compliance with environmental regulations have become increasingly important. Apparently, it is being felt that it is the responsibility of the top management. But, it is the Operation & Maintenance Departments who can substantially contribute to energy conservation and environment preservation. Often "Maintenance" is overlooked as "*necessary Evil*" and is considered as *Consumable rather than producible*. Proper planning and appropriate maintenance strategy can lead to increased capacity utilization & substantial savings. The key words for improving Total Systems Performance of a Cement Plant namely, Production, Quality, Delivery, Safety & Environment, Cost and Morale have a very close relation with maintenance of the plant. The following are the illustrative cases of a better maintenance management in a cement plant.

- In underground mining and crushing there was a substantial increase in production and a substantial decrease in power. Production increased 48.51% in tons per shift. Meanwhile power decreased 32% in kwh per ton.
- The quality of cement produced is of higher order that the no. of consumer complaints have gone down by 64%.
- The Break Down Hours have reduced by 83.21% and the delivery lead time by 70.47%.
- The man days lost due to accidents and safety related problems have been reduced by 84% and the ambient air pollution level has reduced by 40%.

3.0 Effective maintenance management strategies in a cement plant

The development in maintenance management has been based on technological advancements from conventional Breakdown Maintenance to Preventive Maintenance, Predictive Maintenance, and Proactive Maintenance Strategies. Different management theories like Reliability Based Maintenance and Total Productive Maintenance (TPM) approach the selection and utilization of

these technologies from different perspectives. Breakdown Maintenance is possibly the weakest strategy as it is bound to increase down time, energy consumption, production loss of cement, machine/component replacement and also may be the root cause of many safety and environmental disasters. Due to these deficiencies, it is possibly the last choice of a maintenance management function, however still practised many a times rather by compulsion due to many limitations. While it may not be possible to completely eliminate breakdown maintenance, it would be prudent to limit it to applications where the consequence of failure would be negligible for plant availability, energy loss and environment & safety.

Preventive maintenance practices are favoured now-a-days in Cement Industry. Preventive maintenance emphasizes on carrying out periodically scheduled activities on the equipment either to avoid the breakdowns or identify the condition well before it can turn into a breakdown. For example, simple preventive maintenance activity like regular cleaning of motors can give rise to considerable savings in heat losses and also failure of motor windings. Rolling element bearings in coal mill fan, ID fans or Slurry Pump would be changed, irrespective of whether they are damaged or not. Similarly, lubricating oil in the gear boxes of kilns, Raw Mills and Cement Mills would be changed after a predetermined period of working hours. However even preventive maintenance strategy has pitfalls that it is not easy to decide upon such intervals of inspection and replacement. Too frequent Preventive Maintenance activities lead to wastage of production time as well as unnecessary replacement of machine parts and components. Moreover, there is always possibility of human error while performing such inspections and maintenance work and the material consumption may be more than ideal or the human intervention in the equipment technology may aggravate the failure rates rather than obviate it.

Predictive maintenance using Condition Monitoring Techniques can to a large extent, solve the deficiencies of both breakdown and preventive maintenance strategies. Even indirect preventive maintenance, known as subjective condition monitoring using human senses, would be able to identify failures in advance and aid in taking corrective action. Both simple aids and instrumentation enhance the predictive maintenance capabilities to solve many equipment failures, energy losses, environment and safety problems. Proactive maintenance strategy advances over the predictive maintenance technology in its ability to identify machinery deviation even before it begins to develop. The ability of some monitoring instrumentation to track the hydraulic oil contamination even at the ppm trace levels and eliminate them using cleaning equipment simultaneously is an example of proactive maintenance strategy.

4.0 Predictive maintenance & condition monitoring

Predictive Maintenance is carrying out preventive maintenance at what may be irregular intervals, but determining these intervals by the actual condition of the machine. For such condition-based

maintenance to be possible, it is essential to have knowledge of the machine condition and its rate of change with time. The main function of condition monitoring is to provide this knowledge. The knowledge may be obtained by selecting a suitable parameter for measuring deterioration, and recording its value at intervals. Assessing the trend of this measurement can give a useful lead time in warning of incipient machine failure and in planning and organisation of maintenance work. Condition Monitoring would be very useful in the following cement machinery.

- Raw Mill Crushers
- Raw Mills
- Kiln Drive Gear Boxes
- Cooling Fans
- Pumps
- Coal Mill Fans
- Cement Mills
- ID fans
- HT Motors
- Kiln Shell

4.1 Condition monitoring with simple aids

It is wrong notion among us that for carrying out objective condition monitoring, we shall always require complicated instruments. Actually there are methods available and methods could be developed to do the same with simple aids. A few examples of using simple aids for condition monitoring in cement plants are given below.

Example 1: For monitoring the temperature rise of bearings and motors, use can be made of temperature tapes. The tapes are available for different temperature bands. The tape carries windows for different temperature levels within the band. The tape is to be pasted on the surface which needs temperature monitoring. Once a particular temperature level has reached, the corresponding window changes colour, mostly black.

Example 2: V-belts drives used in various rotating machineries like pumps, compressors and blowers can be monitored for right tension using simple aids known as 'Tensiometers'. The instrument is capable of applying a predetermined displacement to the belt and quantifiably measure the force required to produce the same thus predicting whether the belt drive is having proper tension or not.

Example 3: In a flexible pin and bush type of coupling, the wear of the rubber bushes can be easily checked by marking the coupling halves. As the coupling is loaded, the marks separate. As the rubber bush wears, dimension 'A' (the distance of separation of the marks) increases. A maximum value of dimension 'A' can be set as a limit when the rubber bushes are to be replaced. Dimension 'A' can inspected when the coupling is running with the help of a stroboscope.

Example 4: To monitor the condition of lube oil in service a simple aids known as 'Viscosity comparator' and 'Moisture Test Kit' can be used. The viscosity comparator uses the principle of flow differences due viscosity variations between used oil and fresh oil. The moisture test kit finds out the percentage of moisture in the lubricating oil using chemical methods by reacting Calcium Hydride with the moisture present in the oil in a small reacting bottle. The resultant hydrogen emission is used to displace carrier fluid mostly kerosene and measuring the moisture percentages.

4.2 Condition monitoring using modern advanced instruments

In process plants like the modern cement plants, it is also required in addition to use periodic and on-line condition monitoring techniques and systems using sophisticated instrumentation to ensure optimum plant availability and personal safety. Of course, heavy damage to the high speed giant rotating machines can also be prevented by using these techniques. The different techniques and systems used in this category are explained below:

4.2.1. Vibration/signature analysis

This is very advanced technique and is very useful for on-line monitoring of rotating machines like diesel generators, pumps, compressors, gearboxes etc. This technique should be used for critical machines only because it is a costly technique and it requires lot of skill to interpret and analyze the readings. The characteristics used to diagnose the incipient failures and also the nature of failures are amplitude (peak to peak displacement, velocity and acceleration) and frequency of vibration. The principle is that as failure develops, the amplitude of vibration increases and depending on nature of failure, a particular frequency of vibration is generated.The cement industry should have an active programme involving routine noise and vibration measurement, analysis and control on important production and operating machinery to avoid unscheduled shut downs and costly failure. All machines vibrate and make noise - because of mechanical defects, large and small. Excessive vibration or a substantial increase in the normal vibration or noise level of a machine is a warning that there is a deterioration in the component function. There could be many reasons for high vibration. Some of these are.

- Unbalance of rotating parts
- Misalignment of couplings and bearings
- Mechanical looseness
- Bad antifriction bearings
- Bent shafts
- Worn, eccentric or damaged gears
- Bad drive belts and drive chains
- Hydrodynamic forces in case of Pumps
- Aerodynamic forces in case of Fans
- Electromagnetic forces
- Oil whirl

A lot can be learned about a machine's condition and mechanical problems by simply noting its vibration characteristics in terms of frequency, displacement, velocity, acceleration and phase. When analysing a machine's vibration to pinpoint a particular problem, it is essential to know the vibration frequency. Knowing the frequency allows us to identify which part is at fault and what the problem is. The displacement, velocity and acceleration characteristics of vibration are measured to determine the amount or severity of the vibration. Displacement and velocity measurements will be sufficient for majority of cement machinery. Acceleration measurement will be more relevant in case of gear boxes.

Signature Analysis

In many situation a change in the vibration of one frequency component, which is indicative of trouble, can be masked by a more dominant but acceptable vibration at another frequency. In such circumstances frequency analysis is essential. In the frequency analysis process an electrical filter network is employed to reject part of the frequency spectrum whilst allowing another part to pass through the filter. Several sophisticated vibration analysers and signature plotters are available these days. These can analyse and represent the vibration signal in terms of:-

- Amplitude versus frequency;
- Amplitude versus time;
- Amplitude versus frequency versus time;
- Amplitude and phase versus rpm.

The results of this type of analysis, presented as a plot of amplitude versus frequency etc., is referred to as the vibration signature of a machine. Interpretation can be made out of these

signatures in order to find out the possible cause of high vibration. Generally, vibration signatures will be recorded soon after commissioning a new machine, when it is running satisfactorily. These signatures taken in the beginning are referred to as "baseline signatures". Future comparison of vibration readings will be made against these baseline signatures. Once a problem has been identified through analysis, the obvious next step is correction, for which many balancing and other maintenance techniques are available. In the case of gearbox problems, in addition to the spectrum analysis, cepstrum analysis would also be made use of.

Gear Box Problem Diagnosis

In cement plants, the gear boxes are very important because they form integral parts of most critical equipment like Raw Mill, Kiln Drive and Cement Mill. Vibration spectrum analysis alongwith cepstrum analysis would be an effective way of diagnosing gear box problems. The gear box spectrum will contain the meshing frequencies (the number of gear teeth times the rpm of the faulty gear), their harmonics, overtones, side bands, etc. The various problems of gear failure such as excessive gear wear, improper adjustment of backlash, gear tooth inaccuracies, faulty lubrication, gear eccentricity etc., can be detected through the Cepstrum Analysis.

4.2.1 (a) Case Study on Vibration Monitoring & Analysis

This case is pertaining to comparatively an old cement plant where no Data Base is available for the machines to assess the progressive deterioration or to establish the behavioural trend. Therefore, a systematic approach is necessary to achieve the Base Line Data and then to proceed with a planned maintenance methodology. The following two typical machines are considered in this Case.

- Raw Mill Air Separator
- Waste Gas Fan

Raw Mill Air Separator

This Separator was of old design, having a motor pulley system, transmitting drive to a gear box. The entire Separator was supported on four columns. This machine was exhibiting frequent breakdowns and the entire floor was vibrating very heavily. The vibration amplitudes were more than 6000 microns and 80 mm/sec. The dominant frequencies were rotational speed of Drive Motor, harmonics of belt speed, rotational speed of Separator, harmonics of rotational speeds. Phase observations were completely erratic, but steadiness could be seen at specific frequencies. The analysis revealed the following.

- Major misalignment between Drive and Driven system.
- Major unbalance in the Separator rotor.

- Improper matching and fixing of the Gear box base frame.
- Inadequate strength/rigidity of the top frame supporting columns.

Corrective Actions

- Improved the matching and fixing of the Gear box base frame.
- Drive and Driven system aligned to a precision level.
- Major balancing carried out on the separator rotor after a through cleaning.

Results

The Vibration amplitudes came down to 165 microns from more than 6000 microns and the velocity came down to 3.4 mm/sec. from 80 mm/sec.

Further Actions Required

- Improve the structural rigidity of the separator supporting columns.
- Periodically clean the separator rotor at regular intervals.
- Monitor the Vibration pattern at specified intervals to identify progressive deterioration.

Waste Gas Fan

This machine was a radial, single suction fan, situated at higher elevations and mounted on "Vibro Dampers". Highly erratic pattern of Vibration was being observed.

Observations

- Major change from cold to hot condition.
- Frequent balancing, improve the vibration pattern temporarily but again shows considerable increase.
- Frequent shearing of coupling bolts.
- Dominant Vibration frequencies:- rotational speed and harmonics.
- Bearing excitations are not high.
- Non uniform pattern at the machine base frame.

Analysis

- Changes in alignment from cold to hot condition.
- Non uniform behaviour of Vibro Dampers.
- Many Vibro Dampers are not functioning due to jamming of dust and cement in the spring.

- Very high duct load.
- Permanent set of the impeller shaft system during stoppages.

Corrective Actions

- Re-located the Vibro Dampers at the Nodal points.
- Covers are provided to the Vibro Dampers to prevent dust etc., from entering the springs.
- Hot alignment is implemented.
- Suitable expansion provisions for the dust etc., provided and the expansion directed away from the Fan casing.
- Slow turning of the Impeller during stoppages till temperature comes down to atmospheric values to eliminate sag of rotor.

Results

- The unsteady behaviour vanished
- Steady operation of the machine is achieved.

4.2.2. Shock Pulse Method (SPM)

This is very useful and economically viable method to monitor operating condition of antifriction bearings. In fact this technique was developed after observing that the diagnosis of operating condition of antifriction bearings with vibration analyser is extremely difficult as the amplitude is unsteady and frequency is very high. Shock pulse method is based on the principle that when a surface defect is developed on the rolling element or the races, a mechanical shock will be generated. This shock intensity is measured with shock pulse meter in terms of dB to monitor the operating condition of antifriction bearings. A correlation is established between bearing condition and rise in shock value level (SVL) relative to the normal shock value. The interpretation of the results is quite easy and the instrument is very portable.

Rise in SVL (dBN)	Bearing condition
less than 20	Good condition
15-25	Undamaged bearing lacking lubrication or improperly installed
20-35	Damage developing
35-50	Visible damage
50-60	Rise of breakdown

An examination of the reliability of ball and roller bearings showed that their service lives differed considerably. For the purposes of the test, a number of ball bearings were utilized under

identical conditions. After a certain period of time, 10% of the bearings had broken down. However, it took twenty-five times as long for the last bearing to fail. If in the course of preventive maintenance, all ball bearings were to be replaced after a period of time when 10% of the bearings tend to fail, the potential lives of the remaining 90% would be wasted. 90% of the bearings would be replaced too soon, and yet there would be cases of unforeseen bearing failure. On the other hand, if the condition of each bearing is established during operation by continuous inspection and replacement is carried out only when it appears justified, we achieve the following advantages.

- Fewer bearing replacements
- Reduced bearing consumption
- Increased operational reliability
- Less need for planned stoppages for bearing replacements

Rolling-element bearings are used in cement machinery in greater quantities and they are one of the most common types of failure in the cement industry. The probable reasons for failure are excessive load, metallurgical failure, lack of lubrication, use of contaminant lubricants, improper mounting and the completion of the safe working life. The downtime cost is very high in case these bearings fail during operation. At the same time, we can not afford to replace these bearings at fixed intervals due to high cost.

Two cases stated below illustrate the use of this technique in the cement industry.
In a Cement Unit, the shock pulse method is used for CM of rolling element bearings. In the air quenching fan bearings, the shock pulse carpet values are found to be as high as 27 and the maximum values are 36. This has shown that the bearings are running without lubrication. After lubricating the bearings, the shock pulse carpet values and maximum readings have come down to 10 and 21 respectively. This indicates good operating condition. In another cement plant, both the carpet and maximum shock pulse values in a coal mill fan bearing have shown increasing trend. These values have not come down even after lubrication. The bearing condition is regularly watched and a new bearing is procured. It is replaced during a planned shutdown. After the bearing is removed, several pitting marks are noticed on the bearing raceways.

4.2.3. Spectroscopic Oil Analysis Procedure (SOAP)

SOAP is a technique to monitor condition of machines by analysing used oil samples. It is an indirect method. The principle of this technique is that is measures concentration of wear

particles of different elements present in the used oil sample with the help of a 'Direct reading spectrometer'. The wear debris will be microscopic particles forming a homogeneous colloidal suspension in oil. These particles are too small to be removed by filter. A normal wear rate may be established for a particular metal in a particular system. Any condition which increases the friction between moving parts will accelerate the wear rate and thus be detected by SOAP.

4.2.4. Ferrography

Ferrography oil analysis enables a detailed examination to be made of the microscopic particles generated by wearing surfaces and so can yield valuable information about the condition of components. The basic concept involves the magnetic separation of iron and steel (ferritic) wear debris from a lubricant and arranging it, according to particle size, on a glass slide for subsequent examination through a microscope. The particle sizes may range from sub-micron to several hundred microns. During severe wear, when failure is beginning, the deposit will change drastically the total quantity of debris will increase, there will be a greater proportion of larger sizes, and the maximum size will also increase.

4.2.5. Thermography

This technique is based on measurement of infra-red radiation emitted by different materials at different temperatures. The surface of the object to be monitored is scanned with a camera which produces a thermal pattern on a video screen corresponding to the temperature distribution. This helps in locating the hot spots because the intensity of light at each point of the screen depends on temperature at corresponding point on the object. The greatest advantage of thermography instrument is that the hot spots can be detected from a distance without requiring any contact with the object and a big area can be scanned very fast as from maintenance point of view we need to know only the hot spots and not the absolute temperature. Thermography is very useful for monitoring kilns, heat exchangers, etc. to identify failed refractory/insulation conditions and also electrical transmission and distribution systems like cable boxes, circuit breakers, transformer, contractors, insulators, etc. The insulation strength of high voltage motor windings can also be monitored. The thermography inspection has become nowadays a standard practice in many cement plants.

4.2.5 (a) Thermal Monitoring On Kiln Shell

The cement kiln is the most critical equipment in the cement industry, because both upstream and downstream equipments depend upon its performance and availability. Failure of brick lining is a very common cause for the non-availability of the kiln. This may be due to several reasons, as follows.

- Inconsistent quality of kiln feed
- Quality of fuel
- Quality of bricks
- Quality of bricklaying
- Maintenance of operation parameters
- Frequent stoppages of kiln due to mechanical and electrical faults

Because of the multi-faceted nature, this needs an interdisciplinary approach to solve. Frequent stoppages due to mechanical and electrical faults can be reduced by the application of vibration monitoring and analysis techniques. The temperature of the shell surface would give a good indication about the condition of the brick lining. In the past, a common practice in the cement industry was to observe closely the red hot spots on the kiln outer shell. By the time corrective actions were initiated, sufficient damage would have occurred. A recent trend in the modern plants is incorporating infrared temperature monitors in the burning zone of the kiln. Since modern plants are of higher capacity single stream, more sophisticated monitoring of shell surface temperature would be required. The infrared scanner being used in modern cement plants can give the complete temperature profile of the entire kiln without much time lag.

The monitoring system primarily consists of a high speed infrared scanner for measurement of the kiln shell temperature, a computer for analysis of temperature readings and a graphical display screen/printer. Such a sophisticated system enables us to determine the state of lining and coating. It would be possible to monitor the degree of lining wear, location and size of existing or developing hot spots, the location, extent and uniformity of protective coating and the location and the geometry of material rings.

Example 1

In a particular installation, the infrared scanner is located at a distance of 49 meters from the kiln, the scanner head is rotated at the rate of 19 Hz and the entire kiln length is viewed in an 80 degree wedge of each rotation. In each sweep, the scanner senses the infrared radiation emitted from an approximately 30 cm narrow strip along the kiln axis. The readings are continuously fed into the computer and processed and stored in an area of computer memory called kiln temperature array (KTA). Processing consists of converting the scanner signals into temperature readings, collecting data, and determining from where on the kiln surface each measurement originates. The KTA is a two dimensional array where each element contains a temperature reading from a specific spot on the kiln surface, approximately 30 cm^2. The dimensions of KTA

are linear function of the kiln length and circumstance. Thus, the KTA is the real time image of kilns' surface temperature where process information is stored for controlling refractory conditions.

4.2.6. Systematic Application Of Condition Monitoring

One of the problems of condition monitoring is the state of confusion generated by the wide variety of monitoring techniques. Even within the field of vibration monitoring, there is a profusion of measurement methods each with its particular virtue. Each technique requires a special skill and understanding and some of the more useful techniques have been developed only in the last decade.

The key feature of condition monitoring, whatever the technique in use, is the accumulation of data, which at the time of collection seem to have limited value, however, only when sufficient data are collected can normal condition and possible deviations be established and redundant data cease to be accumulated. Thus keeping records is essential to any monitoring programme. To keep paper work to a minimum the data recording system should be devised to provide the important information clearly to the decision maker. Where possible the forms devised for collection of data should also serve to present the information necessary for decision making so that transfer of data is avoided. For example, where the trends in a monitored parameter are used to indicate plant condition it is useful for the data to be plotted directly onto graphs since the mind can absorb visually presented data more effectively than written data. Unfortunately, in the early stages of a monitoring programme there is considerable redundancy in measurements. Only when experience of normal conditions and malfunctions has been obtained will the engineer be able to cut down on the number of measurements made. The importance of recording all relevant particulars of the machine and of the monitoring equipment and tests cannot be over emphasized. One of the most common difficulties encountered by the decision maker, when a monitoring technique detects a trend indicative of failure, is lack of data. Where many machines are operated, consideration should be given to the advantages of computer data storage and presentation.

5.0 Total productive maintenance (TPM)

Technology oriented developments like condition monitoring as described above alone have failed to produce desired results. It was felt that human participation is a vital element in achieving total improvements and hence led to practice of methodologies like TPM in many cement plants. Conceptually, TPM is departure from the "I Operate - You Fix" approach to "I Operate and I maintain" philosophy. It is implementation of productive maintenance by all employees, based on the principle of involvement of all in improving equipment performance from operators to top

management. TPM takes on the challenge of Zero losses, meaning zero failures and zero defects. When there are no failures or defects, equipment effectiveness improves, costs are reduced and stock can be reduced and hence productivity improves. In addition to the tangible effects, TPM also has intangible effects that are not represented in figures like positive work culture, improved motivation levels, dynamic and enthusiastic work force improved working conditions, clean & safer environment etc. The goal of TPM is to maximize equipment effectiveness or in other words the pursuit of economic LCC (Life Cycle Cost) of equipment/physical assets. Industries revolve around man-machine system and TPM aims at maximising the effectiveness of this man-machine system at the minimum LCC. In order to maximise the effectiveness, TPM focuses firstly on "Eliminating Big Losses In Equipment " that interfere with the effective operation of the system. The Big Losses are

Down Time Losses	1. Failures: Downtime losses due to unexpected breakdowns 2. Set Up & Adjustment Losses
Speed Losses	3. Idling & Minor Stoppages 4. Reduced Speed
Defect Losses	5. Defects in process 6. Reduced Yield.

Thus, as can be seen above, TPM results in Overall System Effectiveness/Overall Equipment Effectiveness (OEE) through the combination of the availability, performance efficiency and the rate of quality products. Secondly TPM emphasizes on Periodic Maintenance/Preventive Maintenance. Through Autonomous Maintenance/Small Group activities.

5.1 *Small group activities in TPM*

Small group activities in TPM are of the company-led type. What gave concrete form to this company led type was the overlapping organization of small groups. In general, small group activities are confined to on-the-floor workers, but in TPM an organization is built that overlaps at several levels of group of executives (TPM Promotion Committee) down to small groups of on-the-floor workers i.e. an overlapping organization of small groups. The aim is to have the leaders at each level fulfill roles of connection by acting as members of the small group of the

level above, thus improving vertical and horizontal communication and unifying the top-down, company-led activities and bottom-up, small group activities.

When small group activities only involve on-the-floor workers (especially activities of independent type), they often become stereo-typed or lack vitality. In the case of TPM, however, all employees from top management down to on-the floor workers participate, each level of the organization is aware of its role and the whole company demonstrates a high level of vitality.

5.2 *Autonomous maintenance activities by operators*

Autonomous maintenance activities by operators are one of the main features of TPM, and are a key point in its development. Changing the lack of interest in maintenance on the part of operators, who think that "I'm the operator, and you're the maintenance man"' to developing autonomous maintenance - i.e. "autonomously maintaining the equipment one uses by oneself" - is not something that can be done overnight that it takes two to three years from when TPM is first introduced to when the introduction stage is completely implemented. This is because it takes time to change the attitudes of people. Under this method, the equipment which one is currently operating is used for on-the-job training, and the operator gradually acquires maintenance knowledge and skills through training and implementation at each step. As he moves up through the steps, he gradually gains a willingness to implement TPM. This consists of the following seven steps.

- Initial clean-ups
- Measures against the causes of dust and dirt and places difficult to clean and lubricate
- Formulation of cleaning and lubrication standards
- Overall check-up
- Autonomous check-up
- Orderliness and tidiness
- All-out autonomous management

With autonomous maintenance activities through this step method, the workers and equipment improve as the steps are completed. Splendid results are obtained, including the elimination of the six big losses, improved overall equipment effectiveness and the creation of a pleasant workplace.

5.3 *Steps in evolving TPM program*

The program for developing TPM is divided into twelve steps, from the preparatory stage through the stages of commencement and implementation right up until it has been firmly established.

Step 1 : Announcement by the top management of the decision to introduce TPM: The outcome of TPM depends on the top management itself to firmly resolve to introduce TPM and then announcing this intention to all the employees.

Step 2: Education and campaign on the introduction of TPM; Together with carrying out training at each level so that all employees, from the top down to on-the-floor workers, can correctly understand TPM, a campaign through poster slogans and so on is carried out and an atmosphere for commencing TPM, is built up.

Step 3: Creation of organizations to promote TPM : Creation of such organizations as a company-wide promotion committee, department promotion committees and special working groups for each theme, and the establishment of a TPM promotion secretariat.

Step 4 : Establishment of basic policies and goals of TPM. Survey of the actual situation of overall equipment effectiveness and the six big losses and the establishment of goals and forecast of expected results.

Step 5 : Formulation of a master plan for evolving TPM; Drawing up a schedule for each of the activities that form the pillars in evolving TPM, from preparations for its introduction up to being assessed. Once these various preparations are completed TPM is "kicked off" - i.e. the commencement of its introduction - in Step 6.

The stages of introducing and implementing TPM (Steps 7-11) are the "five activities that form the pillar in evolving TPM" that were described earlier. "Step 7 : Improvement of the effectiveness of each piece of equipment" and "Step 8 : Formation of an autonomous maintenance setup" are commenced immediately after kick-off. When autonomous maintenance activities first begin, the maintenance department shall be very bust backing up the operation section. According "Step 9 : Creation of a planned maintenance set up in the maintenance department" and "Step 10 : Training to improve operation and maintenance skills" commence at least six months after kick-off. It is effective to commence "Step 11: Creation of a setup for the initial management of equipment" after information has been accumulated on the points of disorder in the reliability and maintainability of equipment currently in operation. Once TPM is firmly established - i.e. "Step 12 : Perfection in implementation and increased TPM level" - the

company continues to challenge ever higher targets. The achievements in three years for a cement company as a result of implementation of TPM is indicated in the following table.

FACTOR	IMPROVEMENT %
PRODUCTIVITY	
Production	48.51
Productivity	42.09
Overall Equipment Efficiency	37.27
QUALITY	
No. Of Customer Complaints	64.00
COST	
Specific Power Consumption	21 63
Specific Heat Consumption	09.43
Breakdown Hours	83.21
Breakdown Frequency	61.42
DELIVERY	
Lead Time	70.47
SAFETY	
No. Of Accidents	95.83
Man-Days Lost	84 00
Ambient Air Pollution	40.00
MORALE	
Training Man-Days	228

6.0 Conclusions

The combination of judicious use of the maintenance strategies, predictive maintenance techniques and human participation in maintenance like TPM have been discussed above as the basis of plant maintenance management. It is envisaged that an integrated approach for the implementation of them would lead to greater performance in availability, energy efficiency, safety and environment improvement in cement industries.

Pinch Analysis in Cement Plant

M O Garg
Kinetic Technologies India Limited (KTI)

PINCH ANALYSIS IN CEMENT INDUSTRY

PROCESS SYSTEMS SERVICES DIVISION
KINETICS TECHNOLOGY INDIA LIMITED
NEW DELHI

TRAINING PROGRAMME ON
ENERGY EFFICIENCY AND ENVIRONMENT IMPROVEMENT IN CEMENT INDUSTRY
4 - 6 FEBRUARY 1998

A MANNESMANN COMPANY

PRESENTATION OVERVIEW

- INTRODUCTION TO PINCH TECHNOLOGY
- APPLICATION TO CEMENT INDUSTRY
- CONCLUSIONS

INTRODUCTION TO PINCH TECHNOLOGY

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APPROACHES TO OPTIMISE HEAT RECOVERY

- TRADITIONAL APPROACH BASED ON EXPERIENCE
- MATHEMATICAL METHOD
- THERMODYNAMIC METHOD

TRADITIONAL APPROACH

- LARGELY BASED ON HEURISTICS OR PREVIOUS DESIGN EXPERIENCE
- SEVERAL ALTERNATIVES NEED TO BE GENERATED AND SIMULATED TO ESTABLISH THE BEST
- POSSIBILITY OF SUB-OPTIMAL DESIGN

MATHEMATICAL METHOD

- FORMULATE THE DESIGN AS A MATHEMATICAL OPTIMIZATION PROBLEM
- REQUIRES HIGH DEGREE OF MATHEMATICAL SKILL AND PROGRAMMING EFFORT
- LITTLE OR NO PHYSICAL INSIGHT - USE OF BRUTE FORCE

THERMODYNAMIC METHOD

PINCH TECHNOLOGY

- USER-DRIVEN APPROACH IN THE DEVELOPMENT OF ENERGY AND PROCESS SYSTEMS
- SET ENERGY AND CAPITAL TARGETS BEFORE DESIGN
- ANALYSIS BASED ON PHYSICAL INSIGHT

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PINCH TECHNOLOGY APPROACH

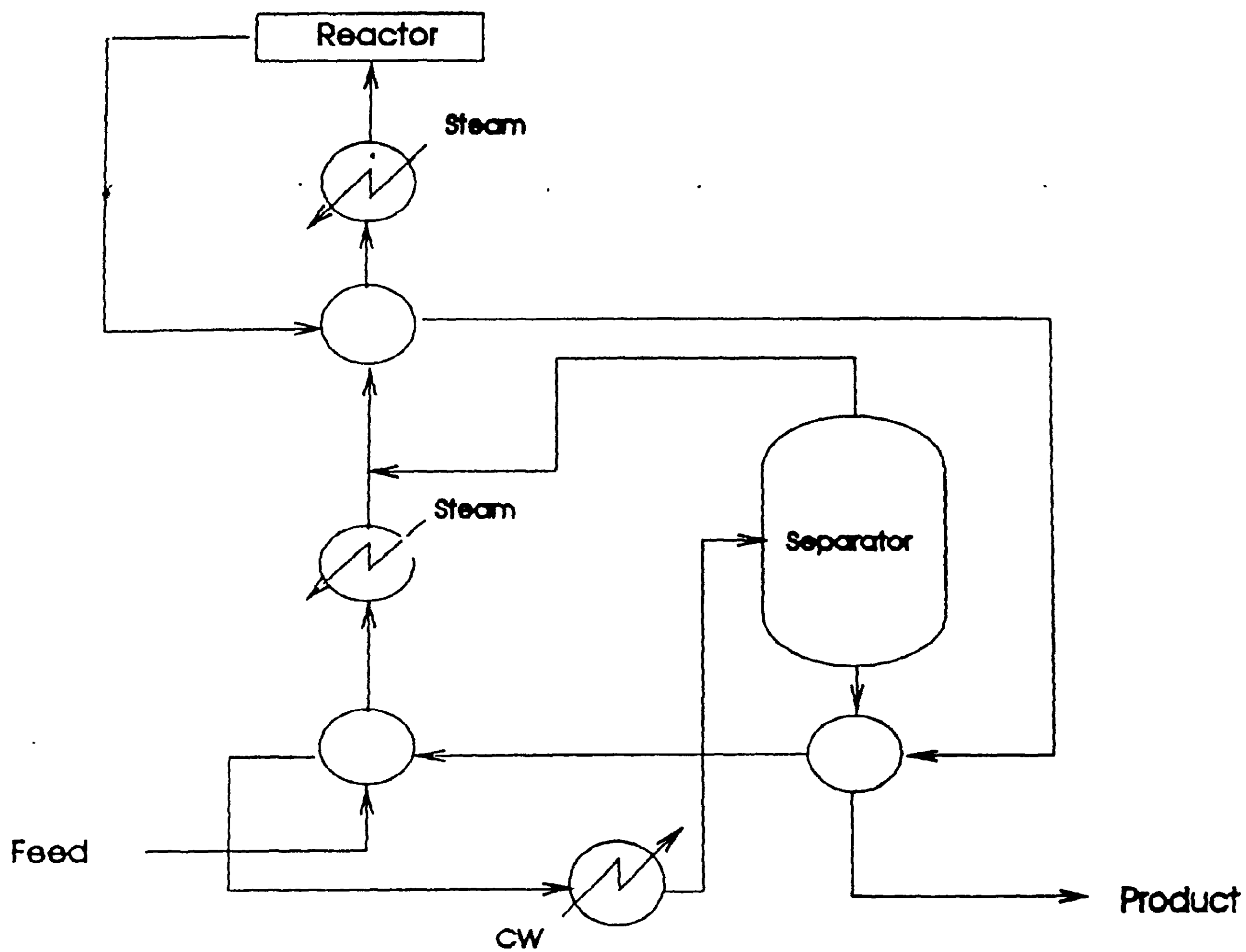
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PINCH TECHNOLOGY TOOLS

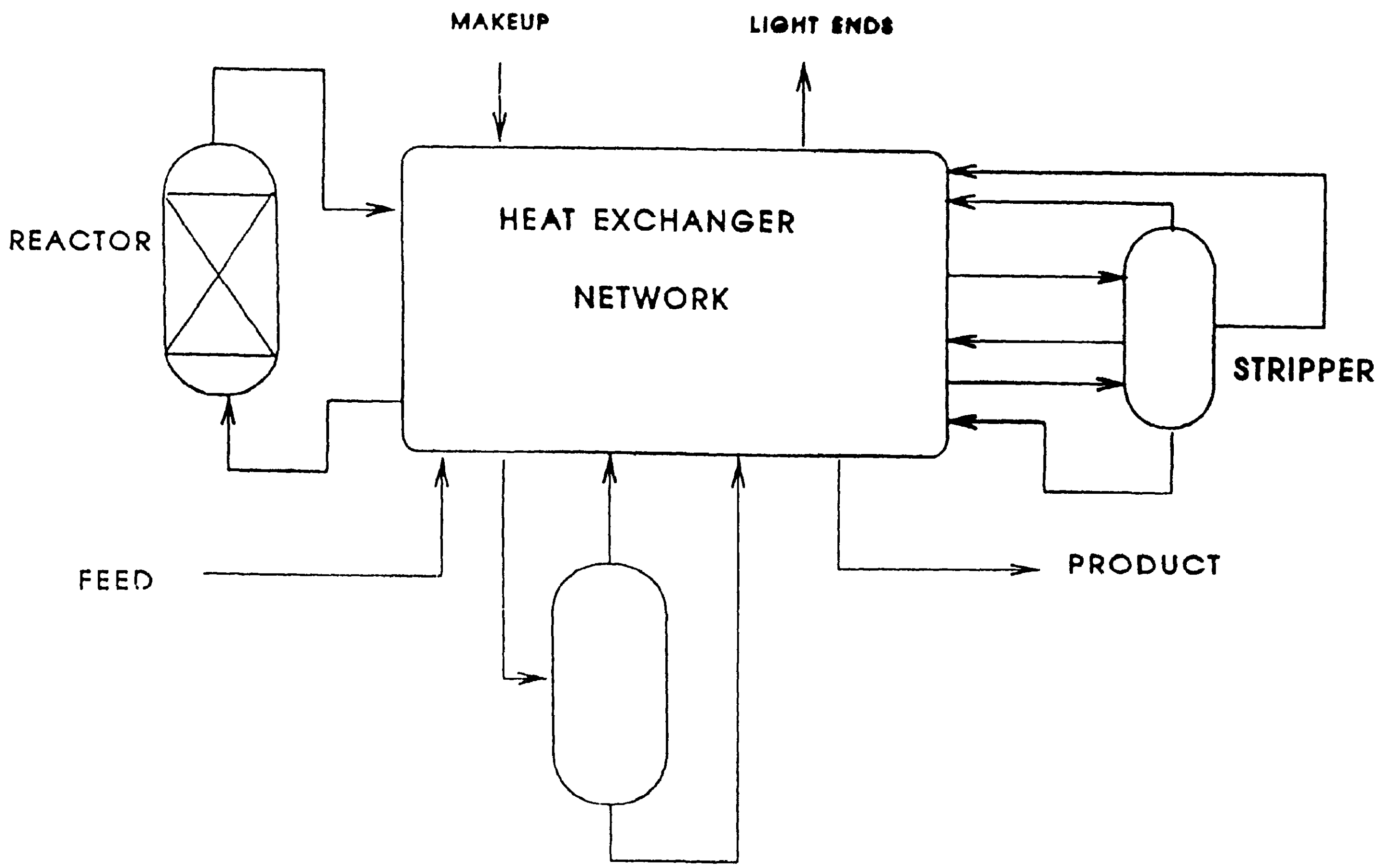
- COMPOSITE CURVES
- GRAND COMPOSITE CURVES
- AREA vs ENERGY PLOT

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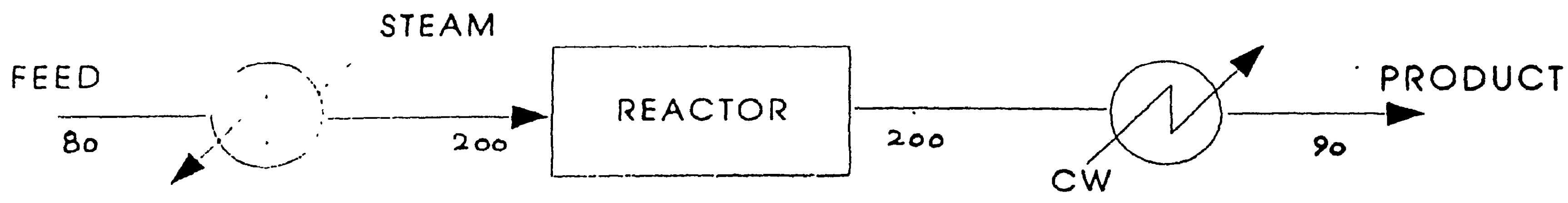
A TYPICAL PFD

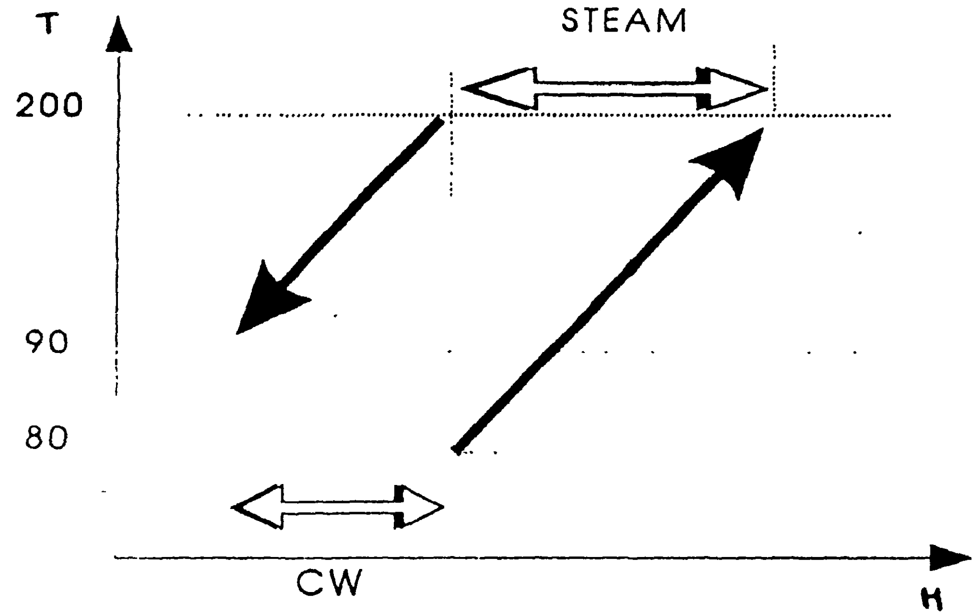


GENERAL PROCESS PLANT

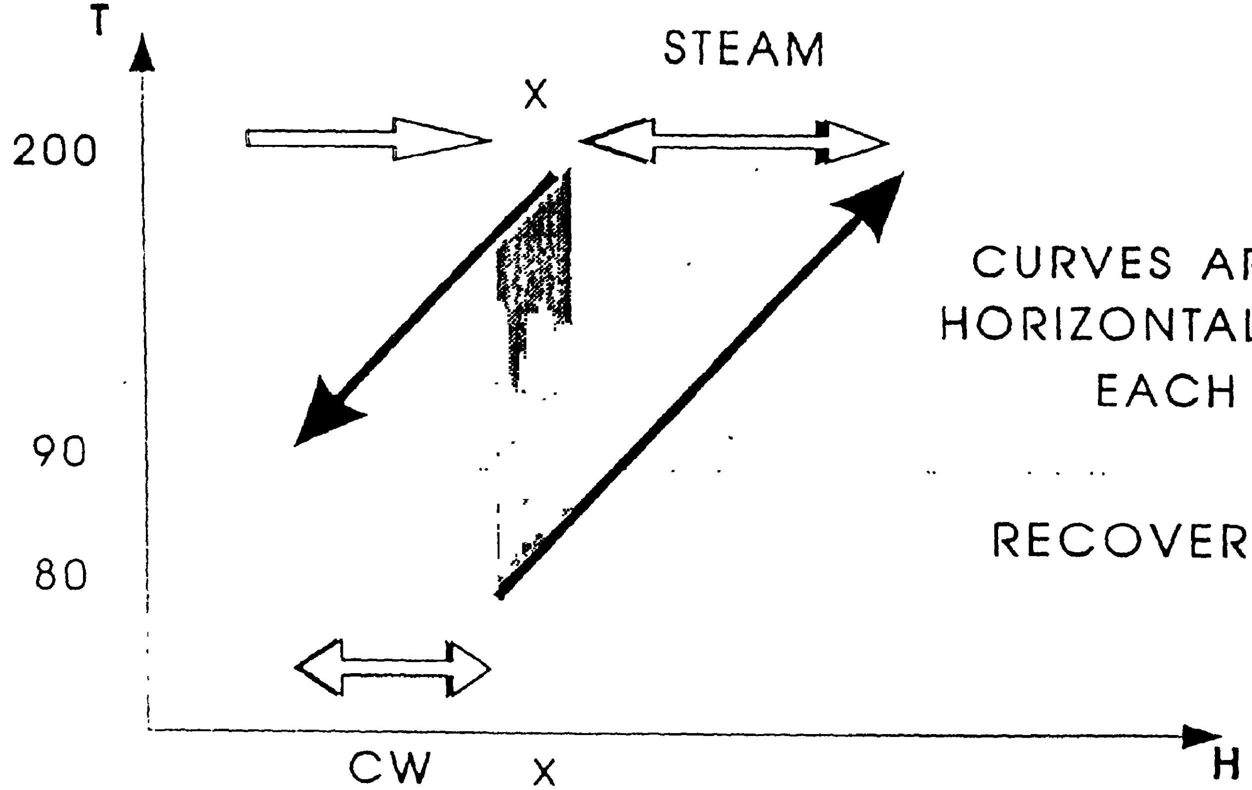


CONSIDER THIS SIMPLE PROCESS ...





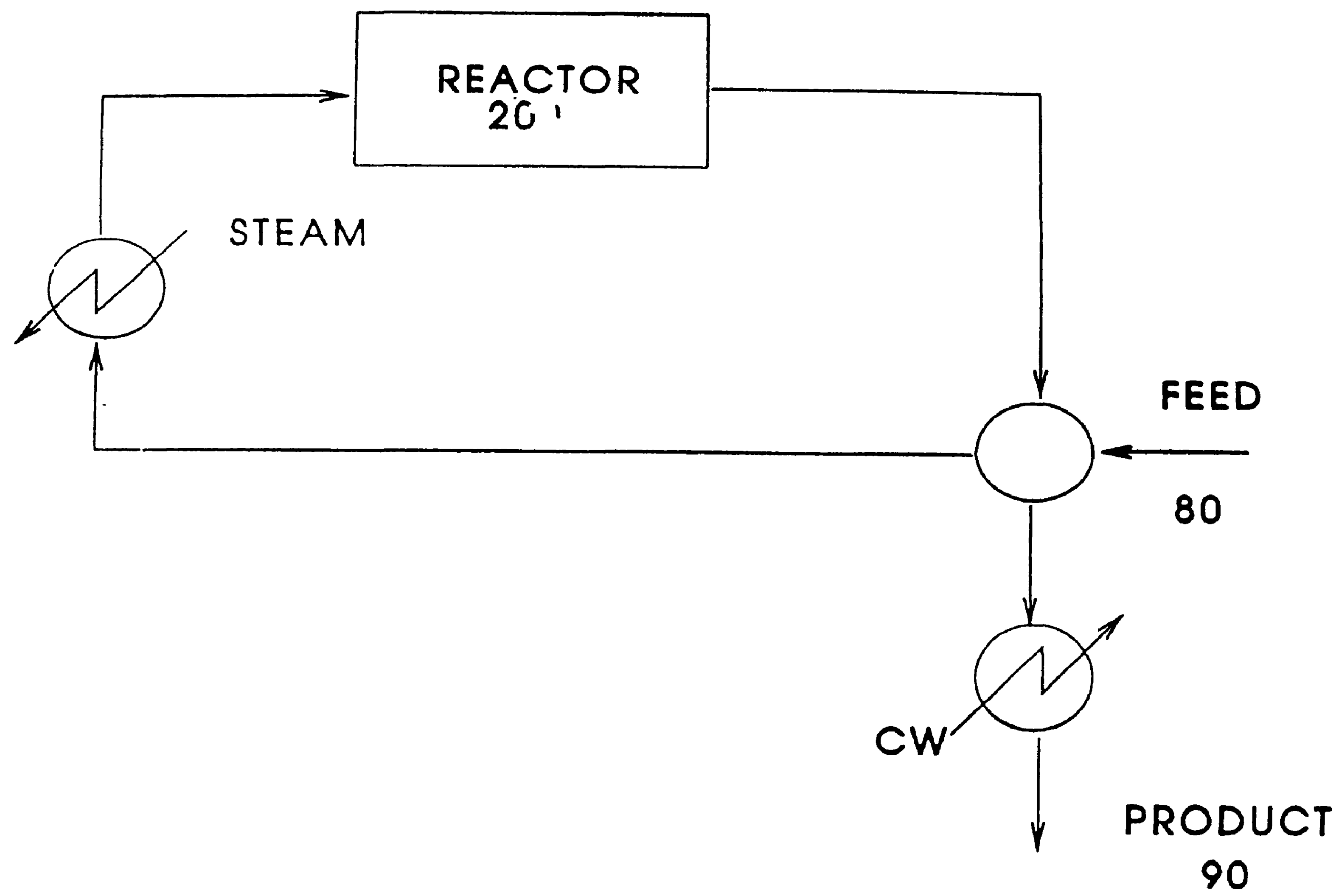
PROCESS HEAT EXCHANGE REDUCES BOTH STEAM AND COOLING WATER



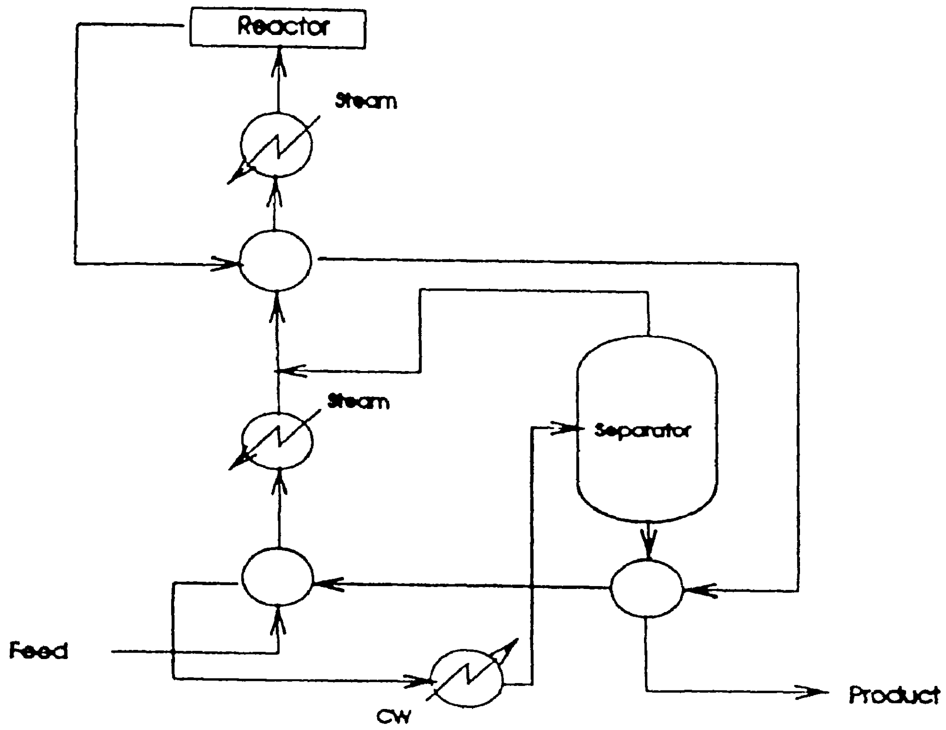
CURVES ARE 'SHIFTED' HORIZONTALLY TOWARDS EACH OTHER

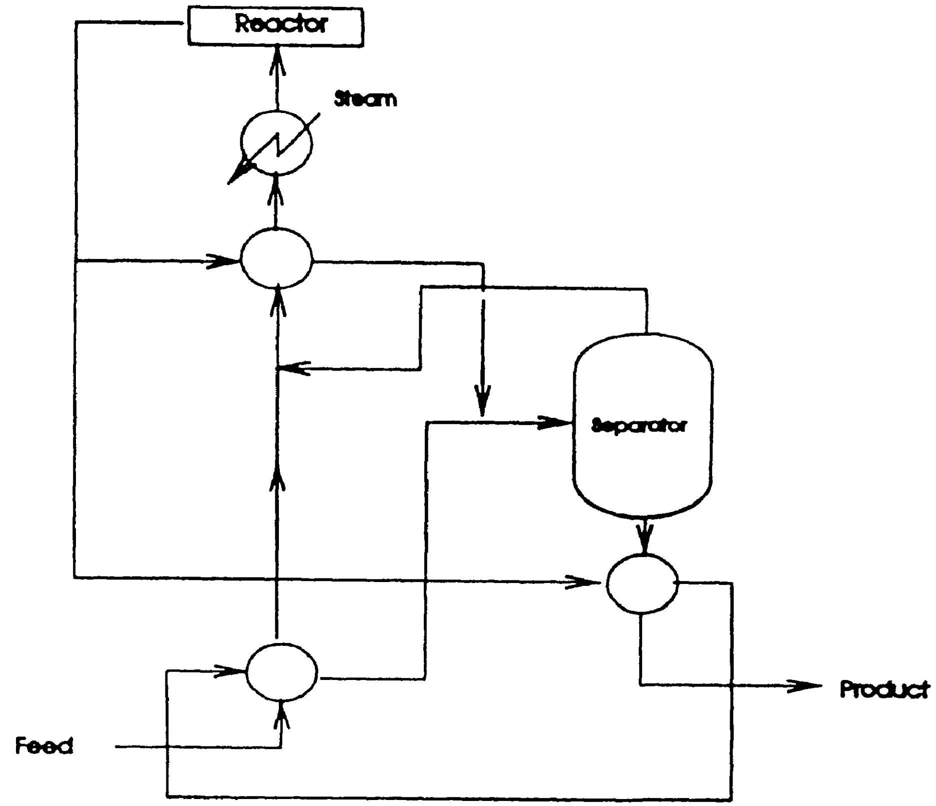
RECOVERED HEAT = X

IMPROVED DESIGN ...



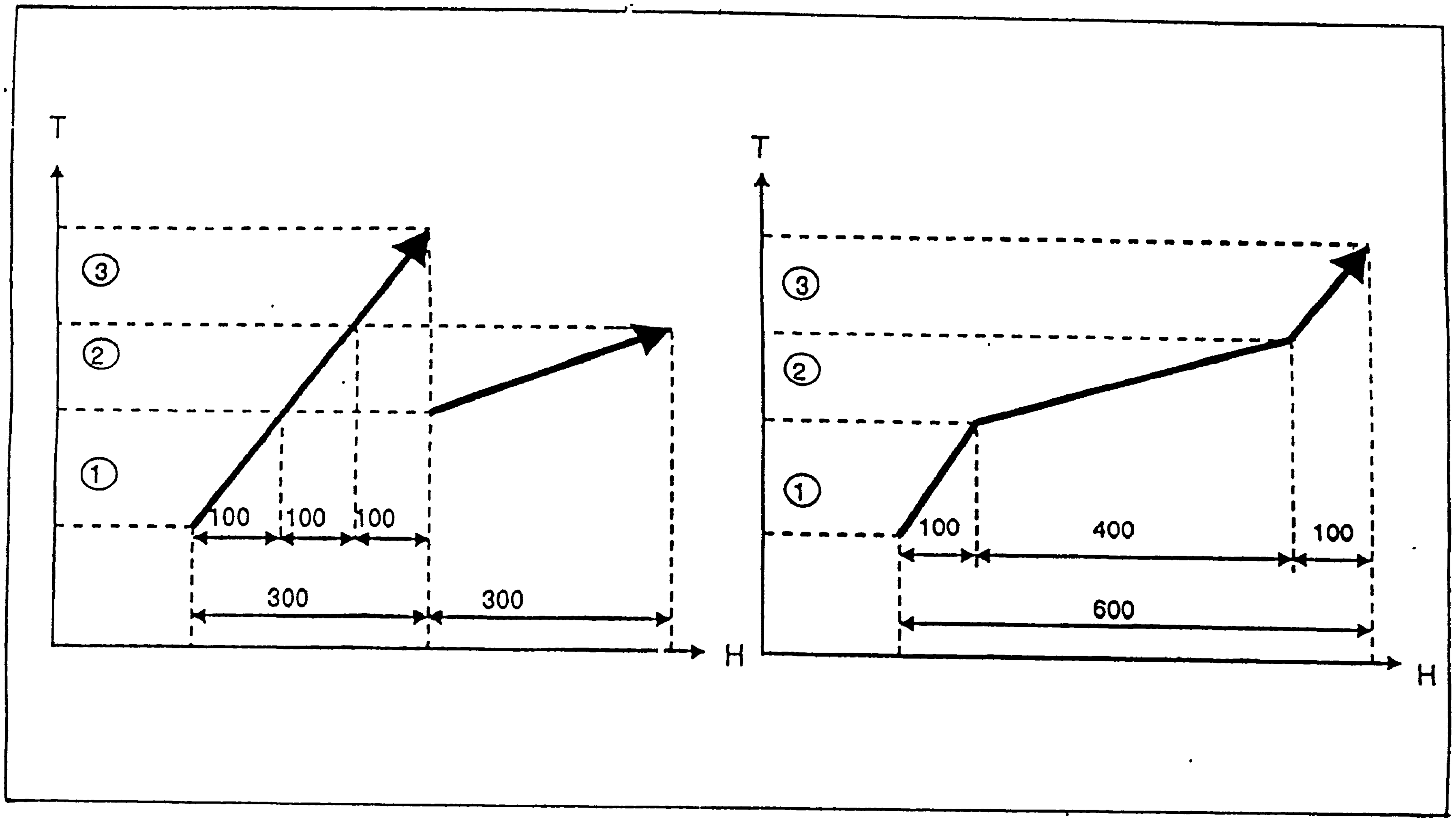
DESIGN COMPARISON FOR SIMPLE PROCESS

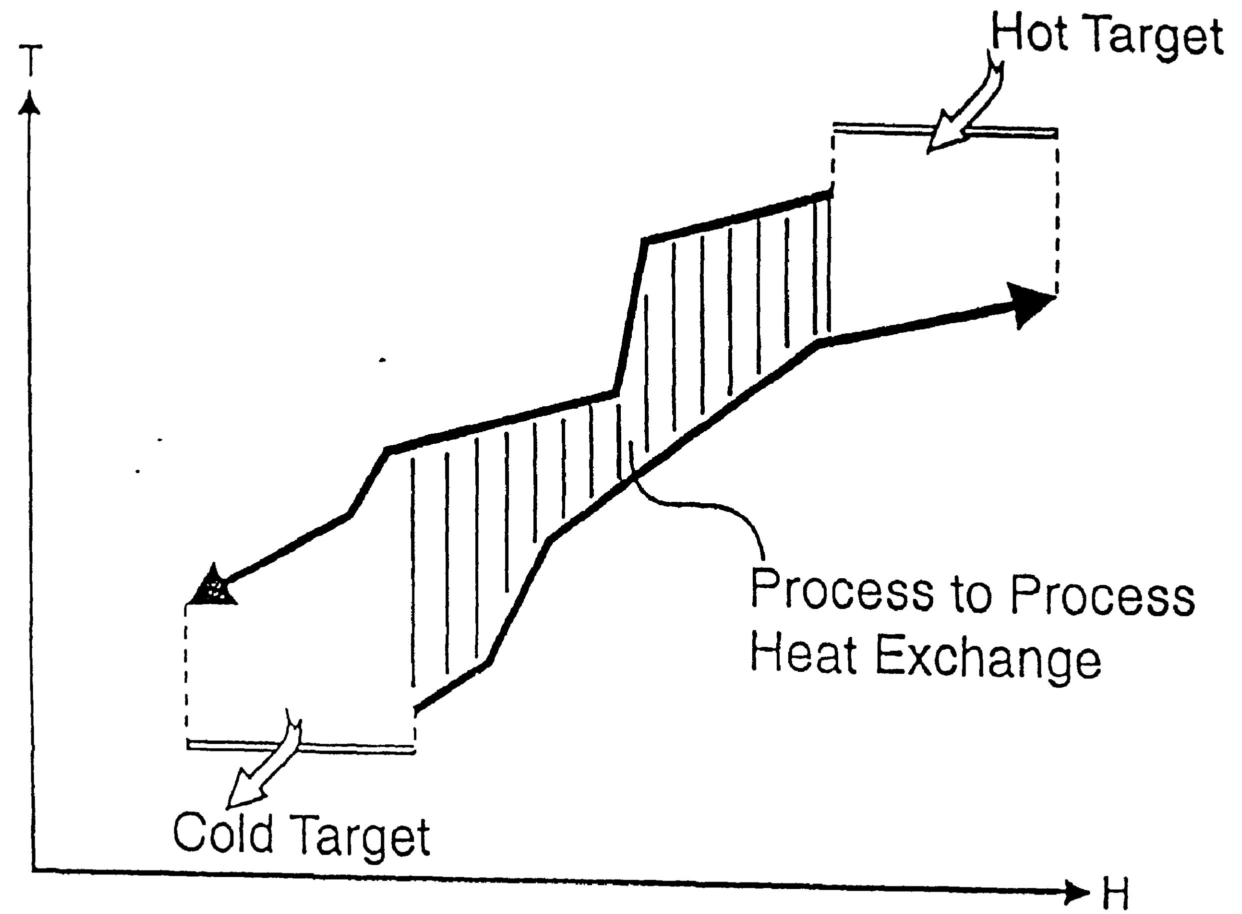




STEAM	=	1722	STEAM	=	1068
CW	=	654	CW	=	0
AREA	=	629	AREA	=	533

THE CONCEPT OF COMPOSITE CURVE

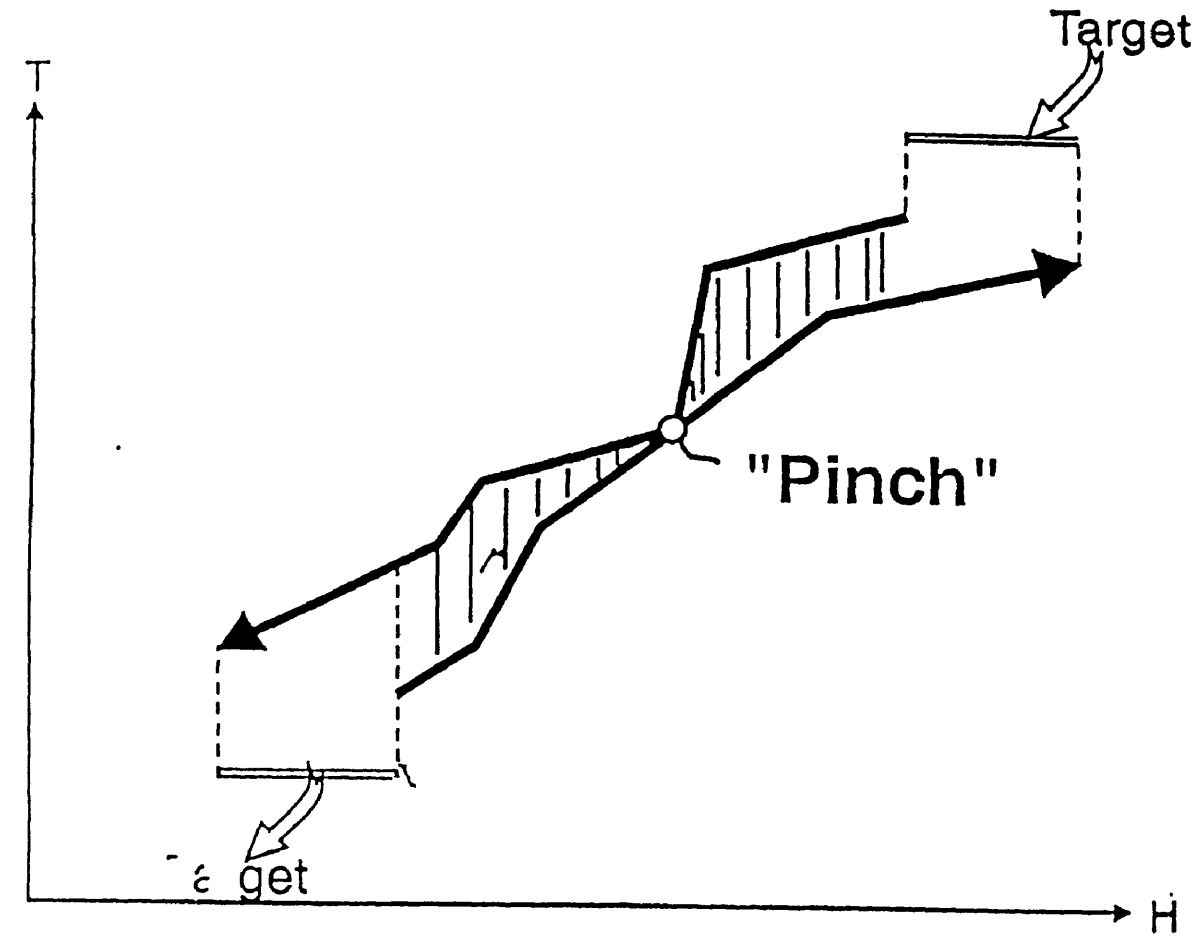


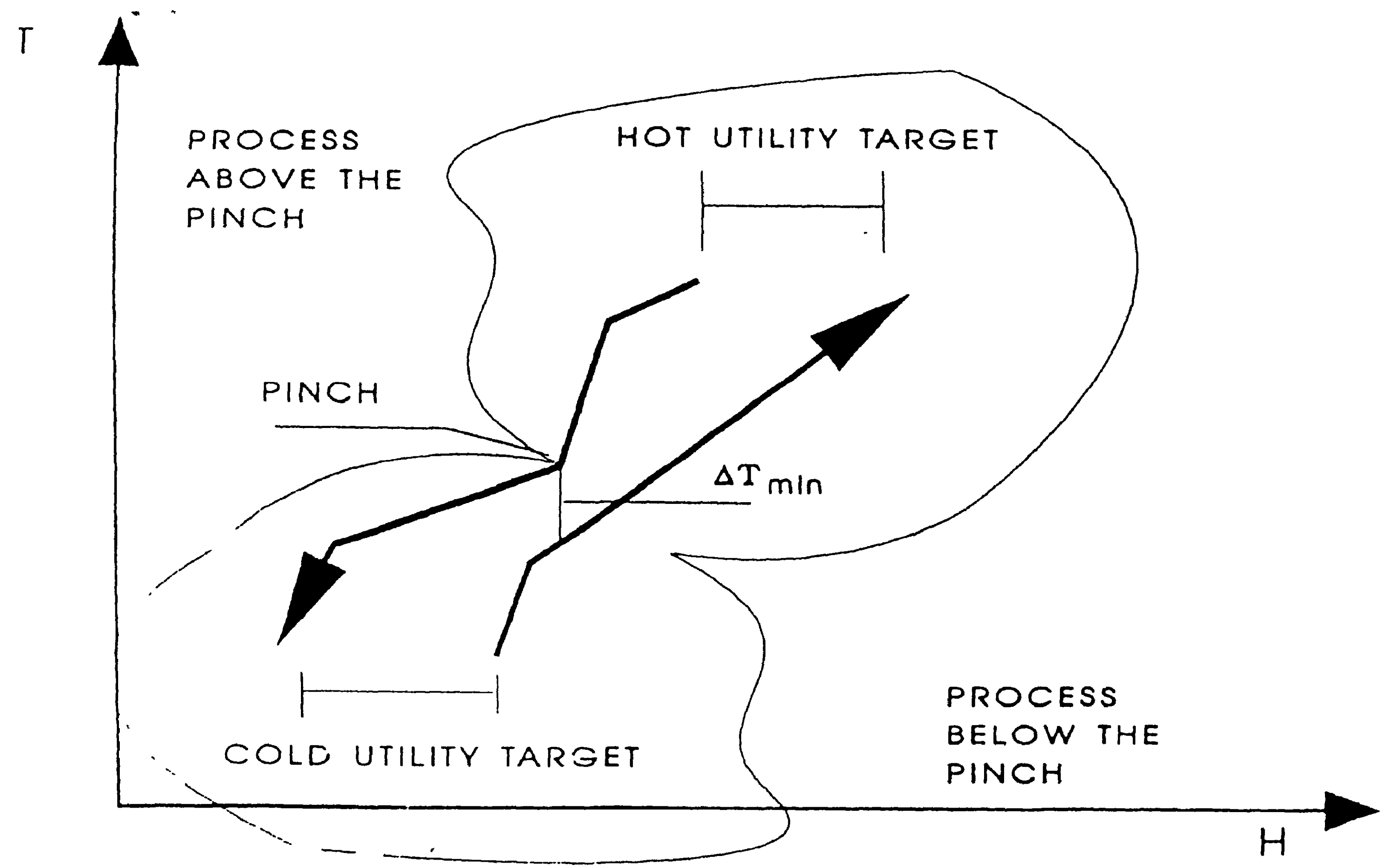


Hot and Cold Composite Curves

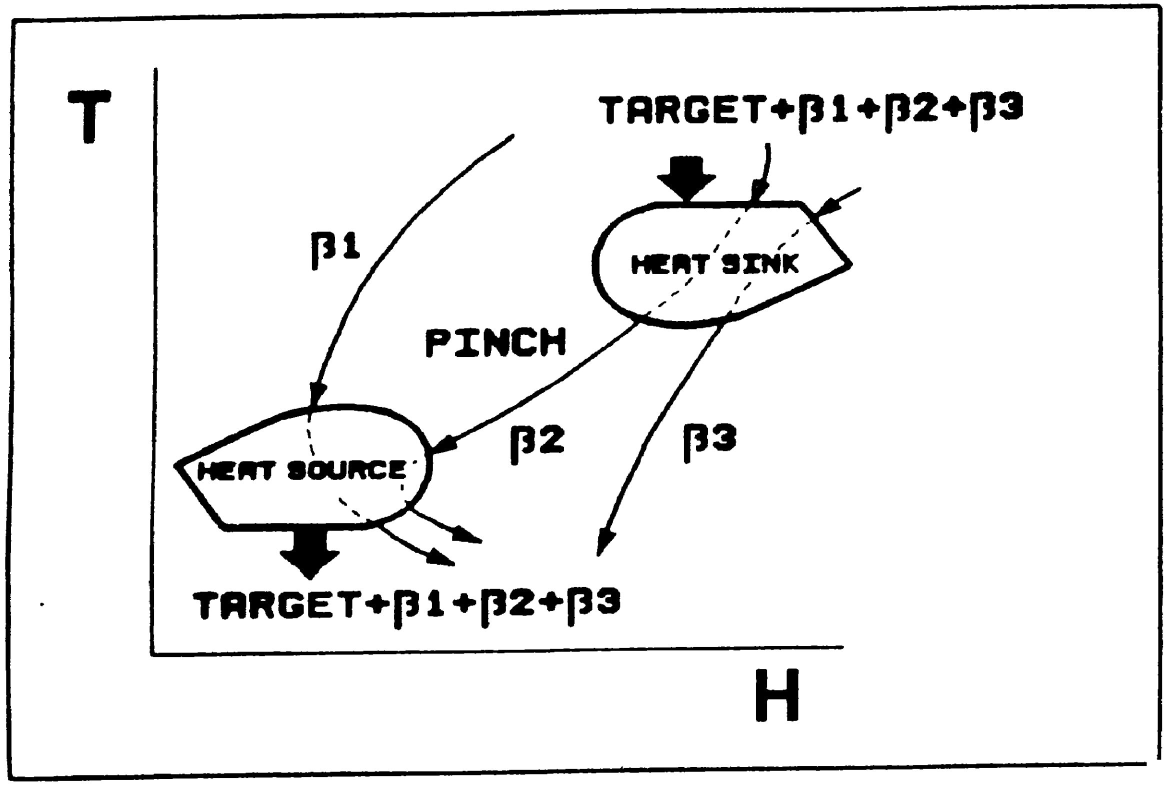
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T
Target
"Pinch"
get
H


T
PROCESS ABOVE THE PINCH
HOT UTILITY TARGET
PINCH
ΔT min
COLD UTILITY TARGET
PROCESS BELOW THE PINCH
H

THREE IMPORTANT RULES FOR DESIGN:

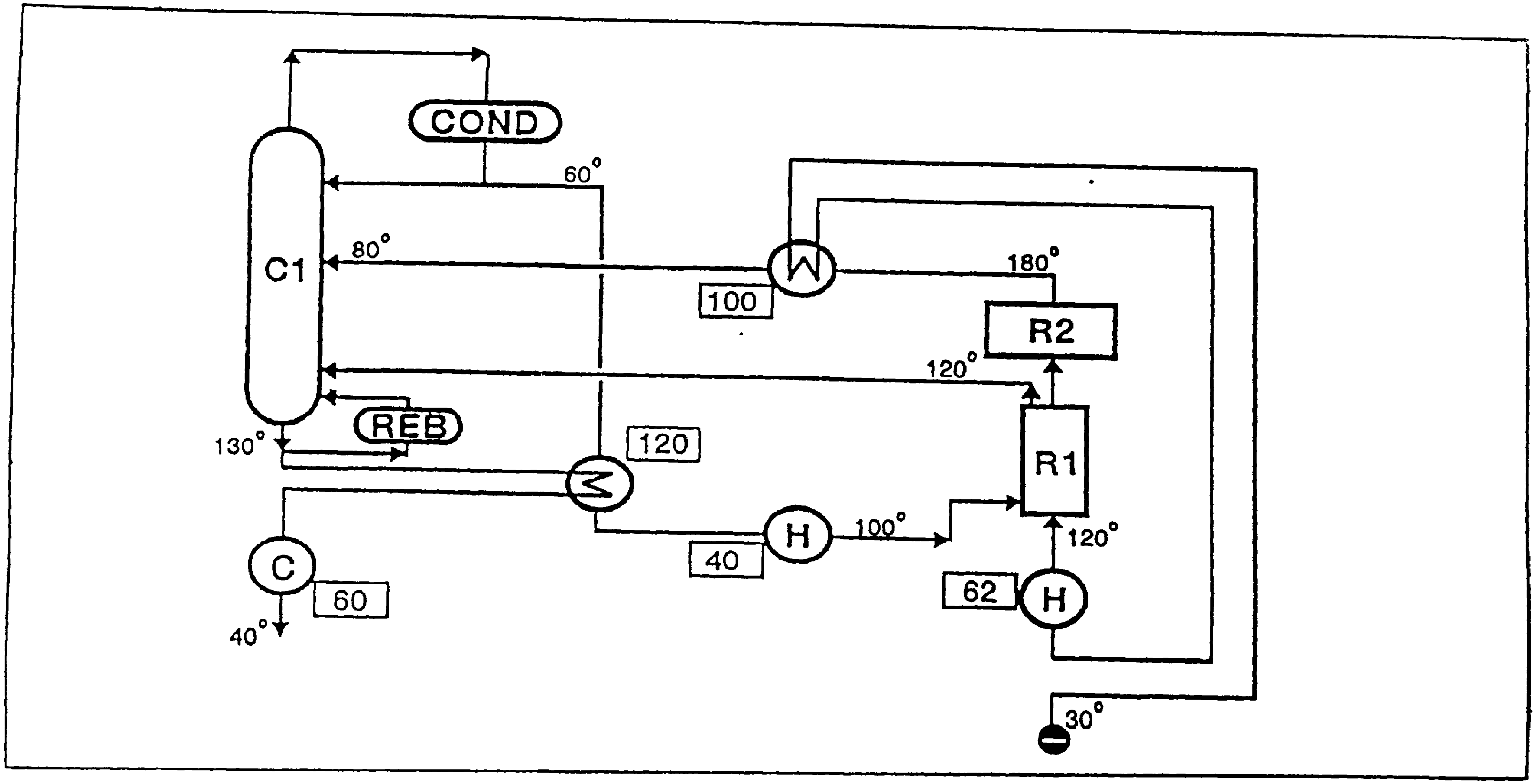


- NO PROCESS HEAT ACROSS ($\beta 2=0$)
- NO COLD UTILITY ABOVE ($\beta 3=0$)
- NO HOT UTILITY BELOW ($\beta 1=0$)

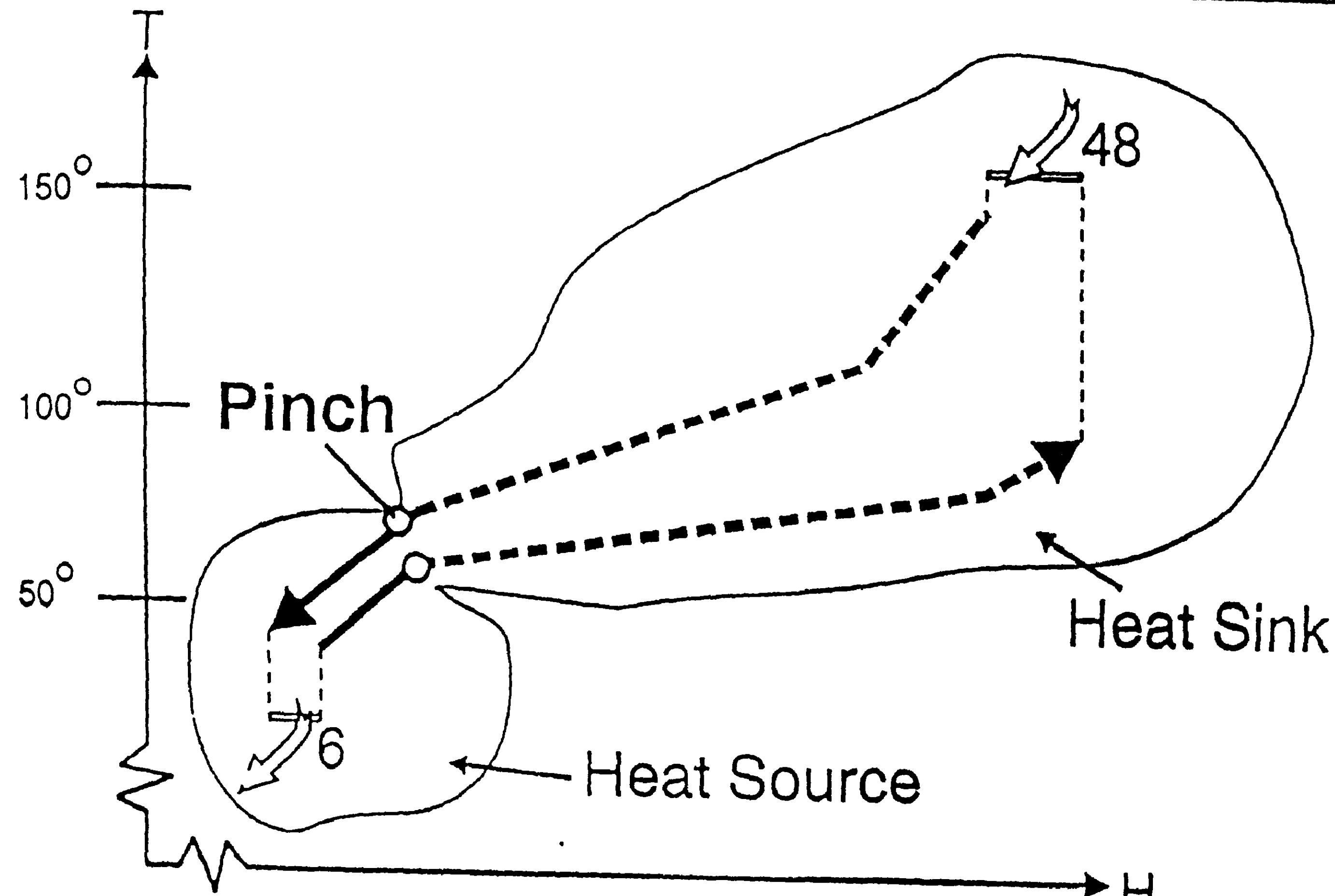
EXAMPLE OF APPLICATION

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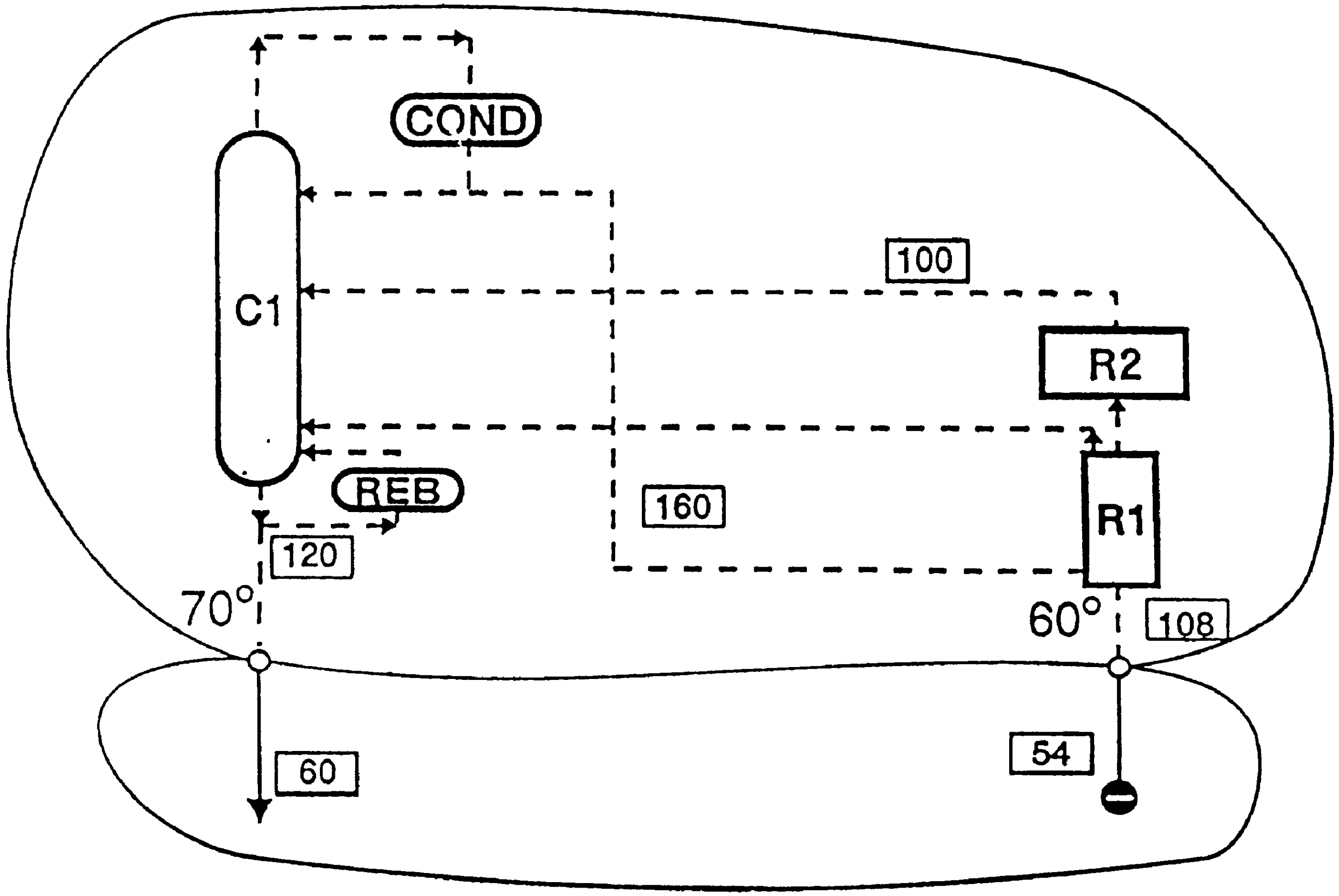
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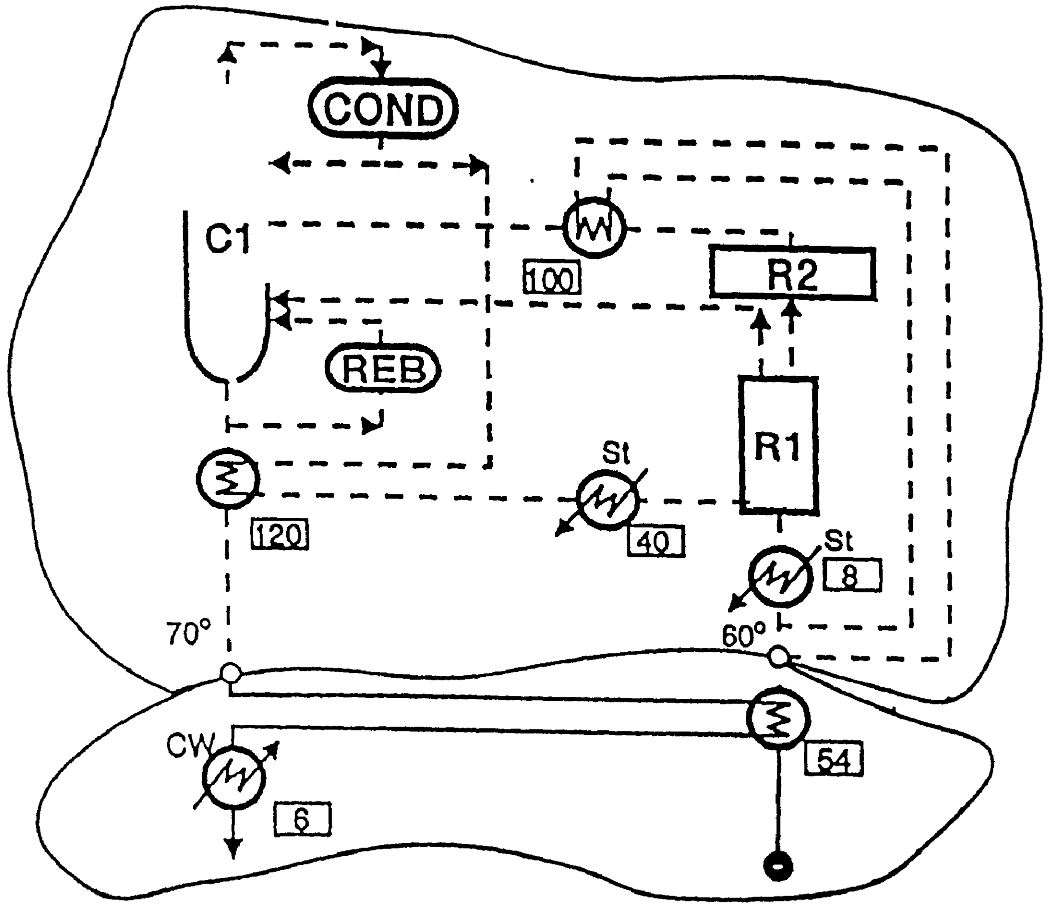
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Identify Source and Sink



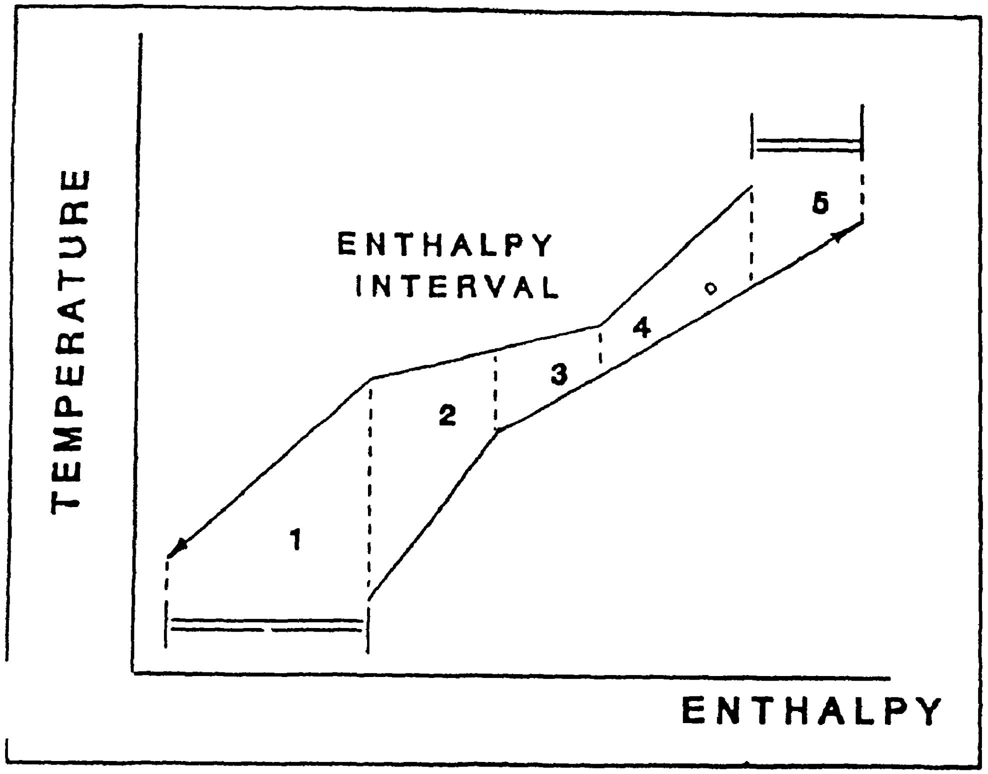
Divide at the Pinch



Design in Two parts ⟹ Targets Achieved

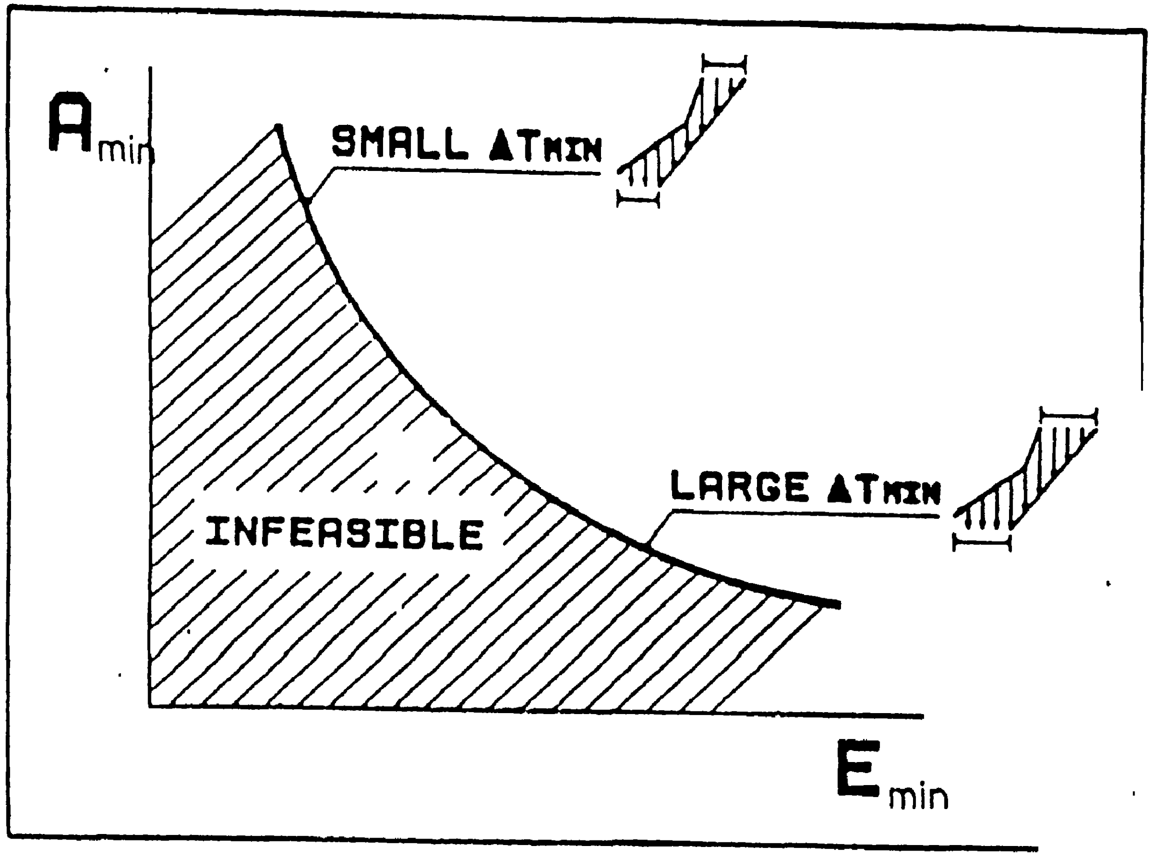
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COMPOSITE CURVES... AREA TARGET

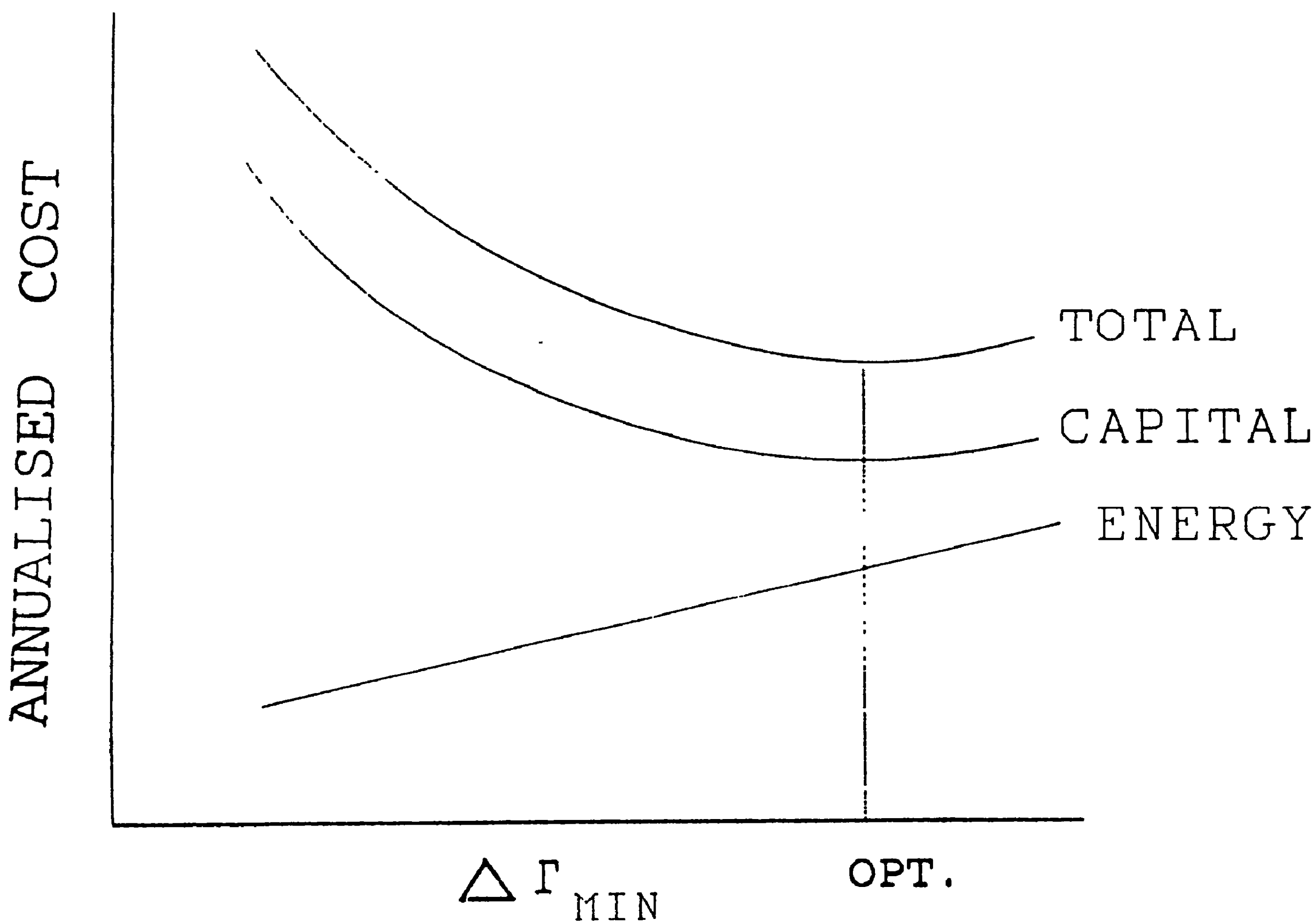


$$A_{min} = \sum_{interval} \frac{1}{\Delta T_{LM}} \sum_{j\ streams} \left(\frac{q_j}{h_j} \right)$$

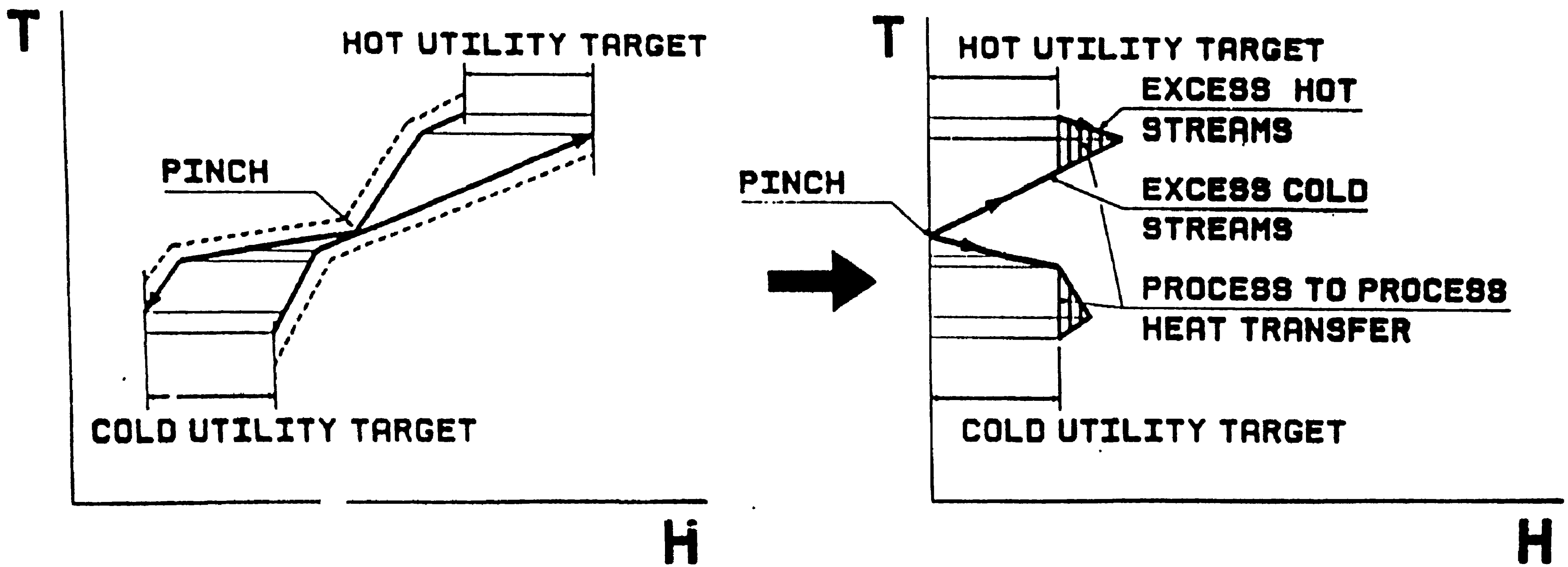
ENERGY AREA PLOT



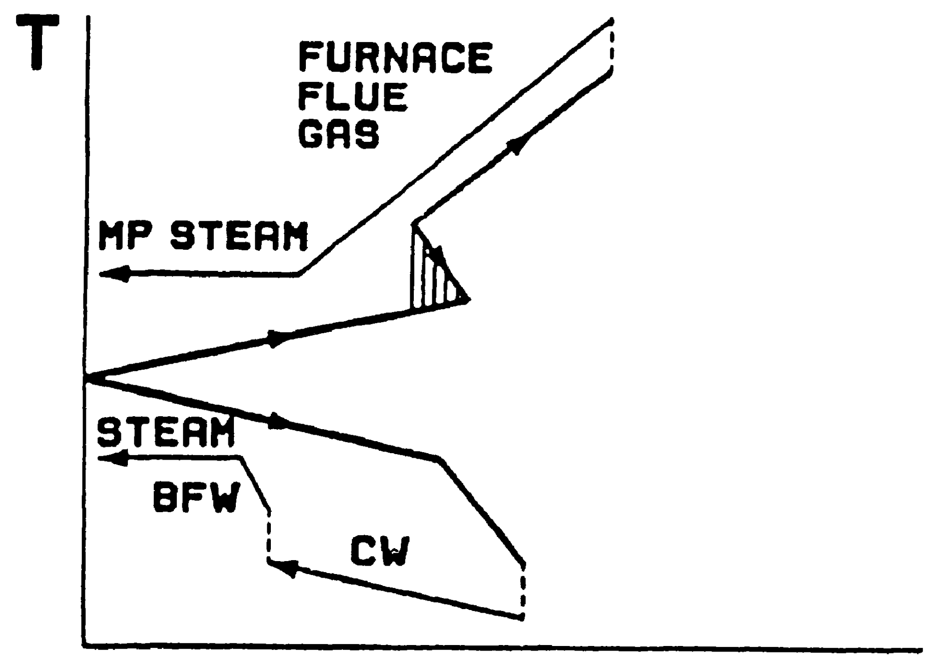
ENERGY / CAPITAL TRADEOFF



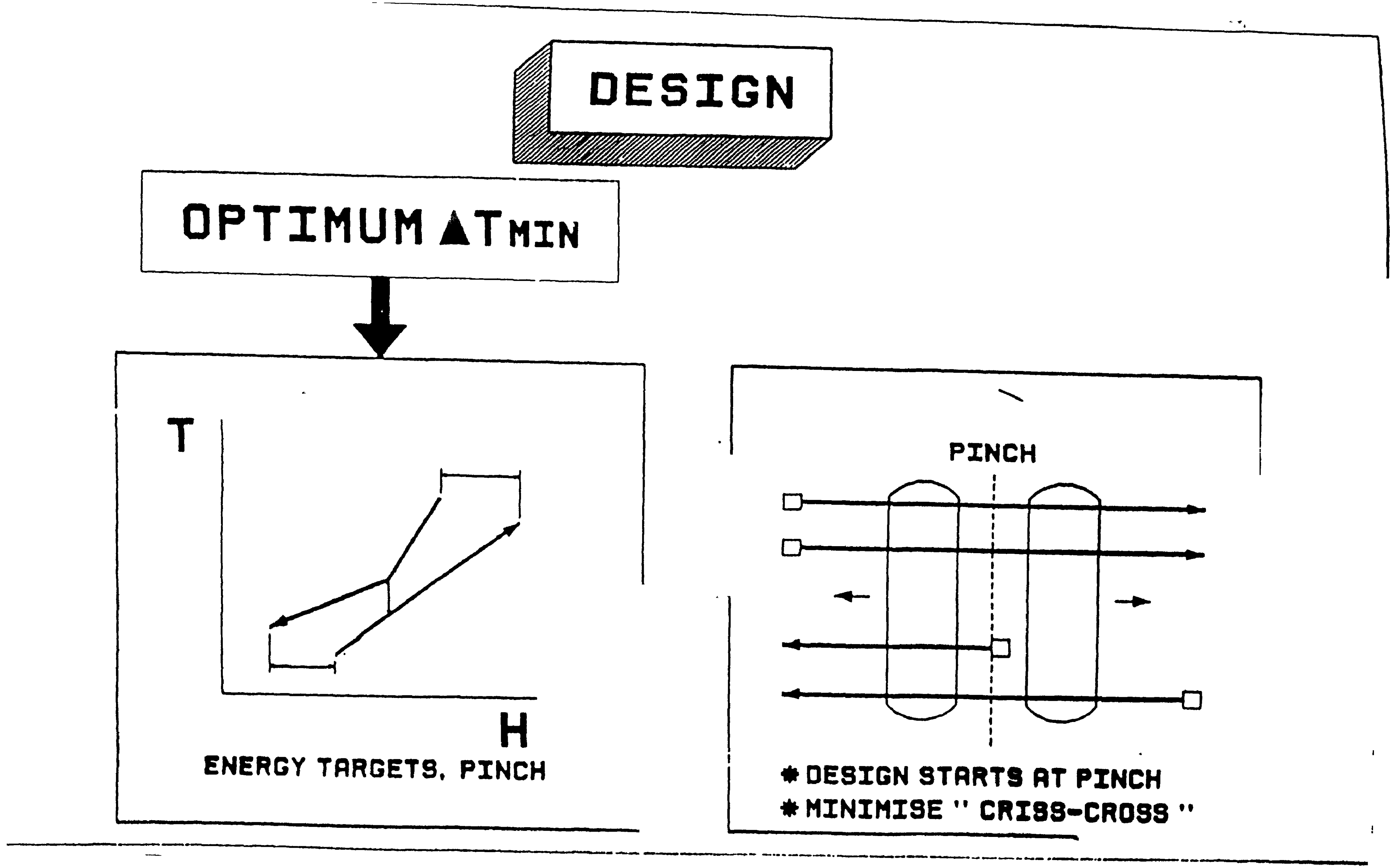
GRAND COMPOSITE CURVE



USE OF GRAND COMPOSITE CURVE



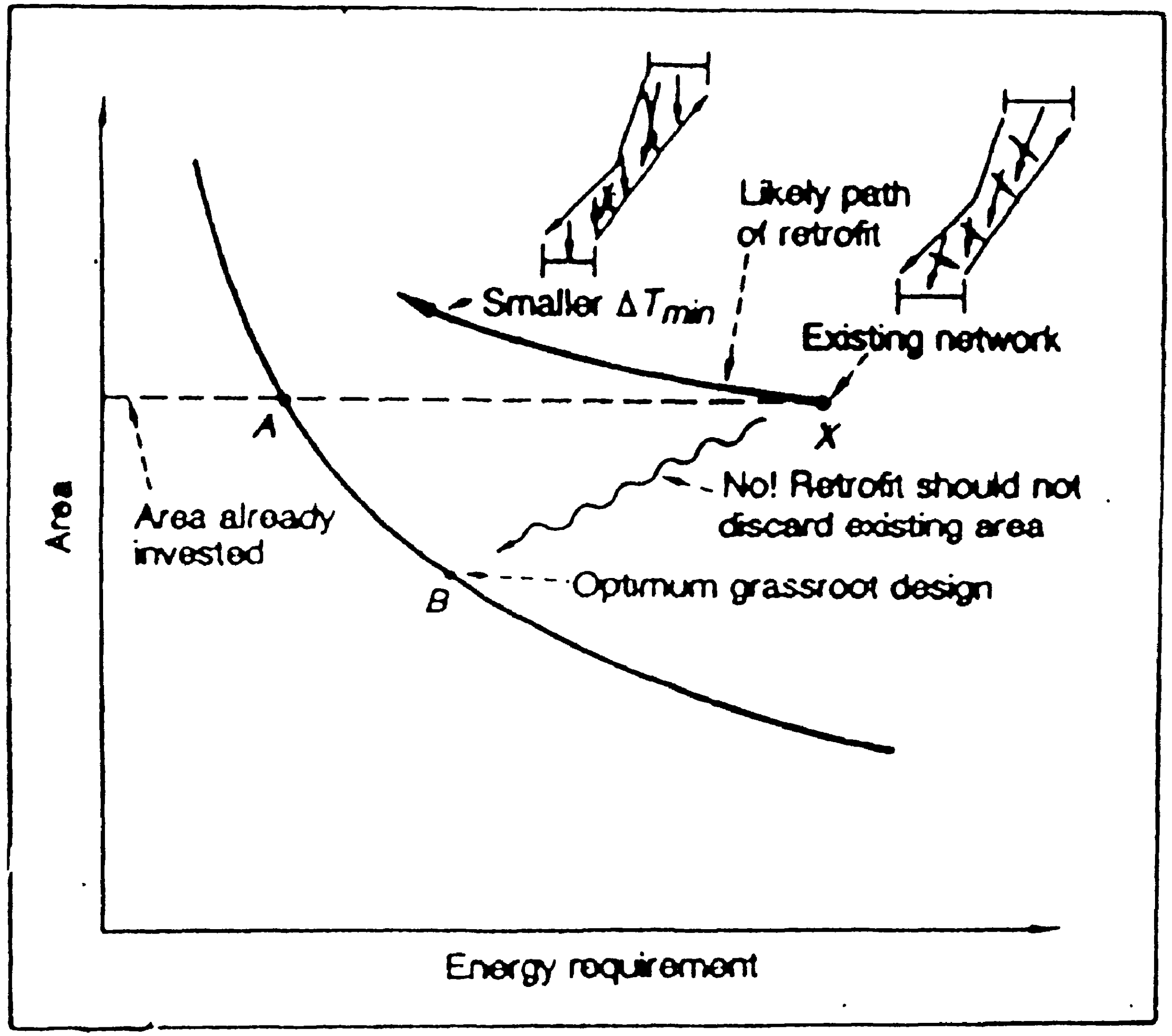
WE CAN SELECT APPROPIATE
UTILITY LEVELS


DESIGN
OPTIMUM ΔTMIN
T
H
ENERGY TARGETS, PINCH
PINCH
* DESIGN STARTS AT PINCH
* MINIMISE " CRISS-CROSS "

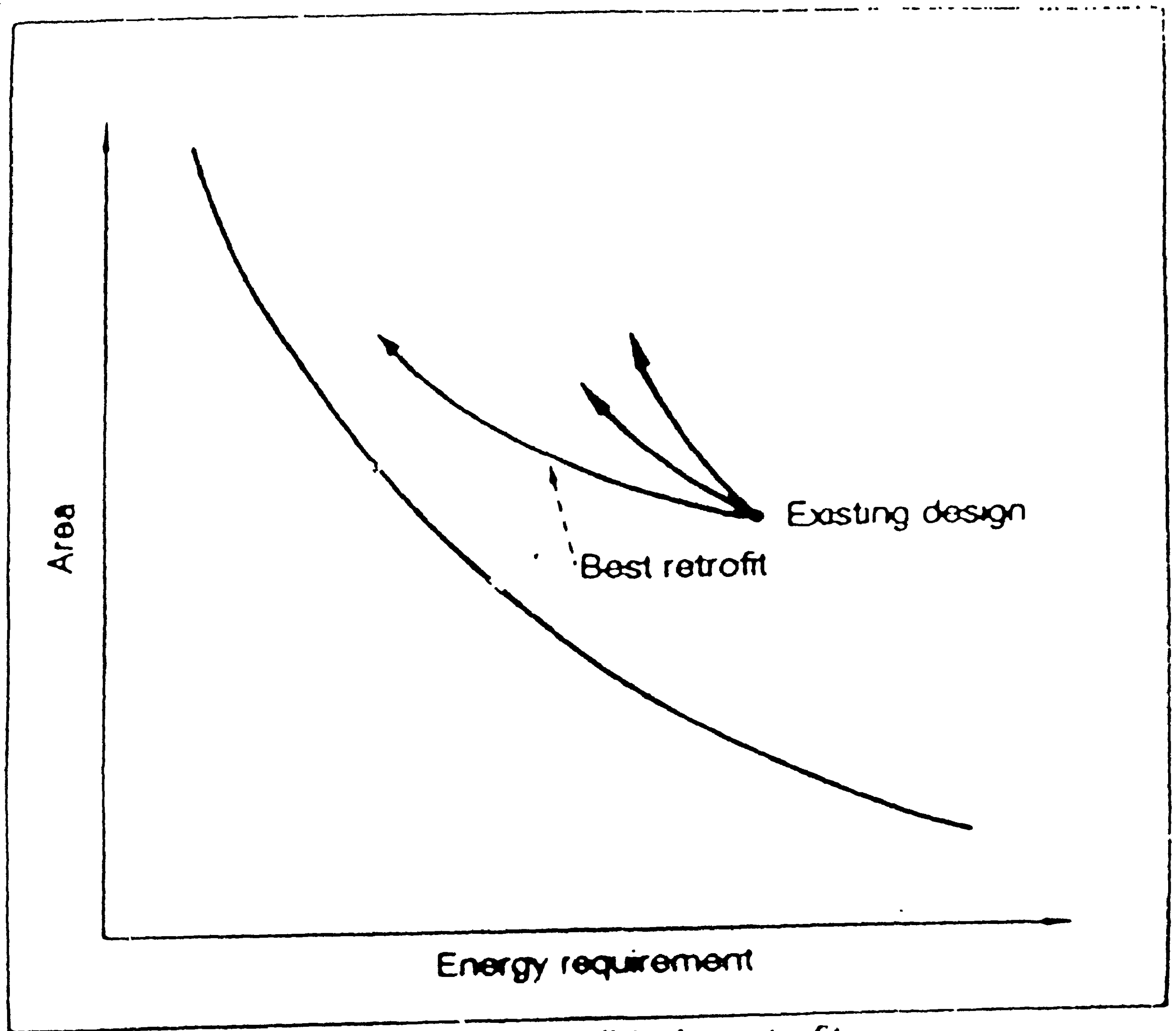
RETROFIT

KTI

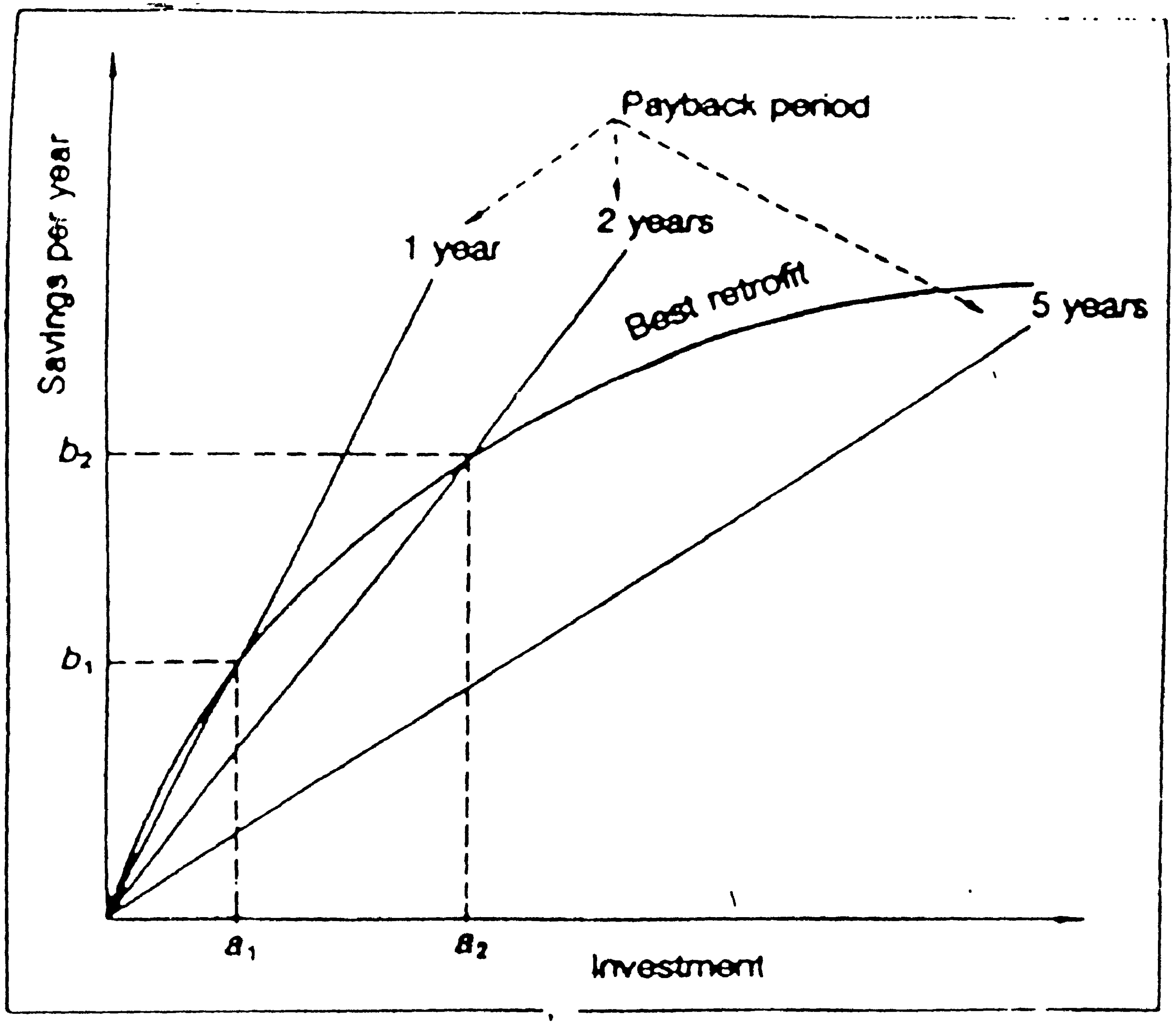
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A retrofit should try to reach
Point A, not B, to take full advantage of the existing area



Many paths are possible for retrofit,
but bottom curve, whose shape is typical, is the best



Best curve for area/energy
can be translated into a savings/investment plot

PINCH TECHNOLOGY : APPLICATIONS IN ...

- REFINERY
- PETROCHEMICALS
- FERTILIZERS
- SPECIALITY CHEMICALS
- BREWERY
- FOOD PROCESSING
- PULP AND PAPER
- CEMENT
- TEXTILES
- SUGAR

INTRODUCTION

- CEMENT INDUSTRY IS A LARGE CONSUMER OF ENERGY

SOURCE	APPROXIMATE COST,%
POWER	27
FUEL (COAL)	73

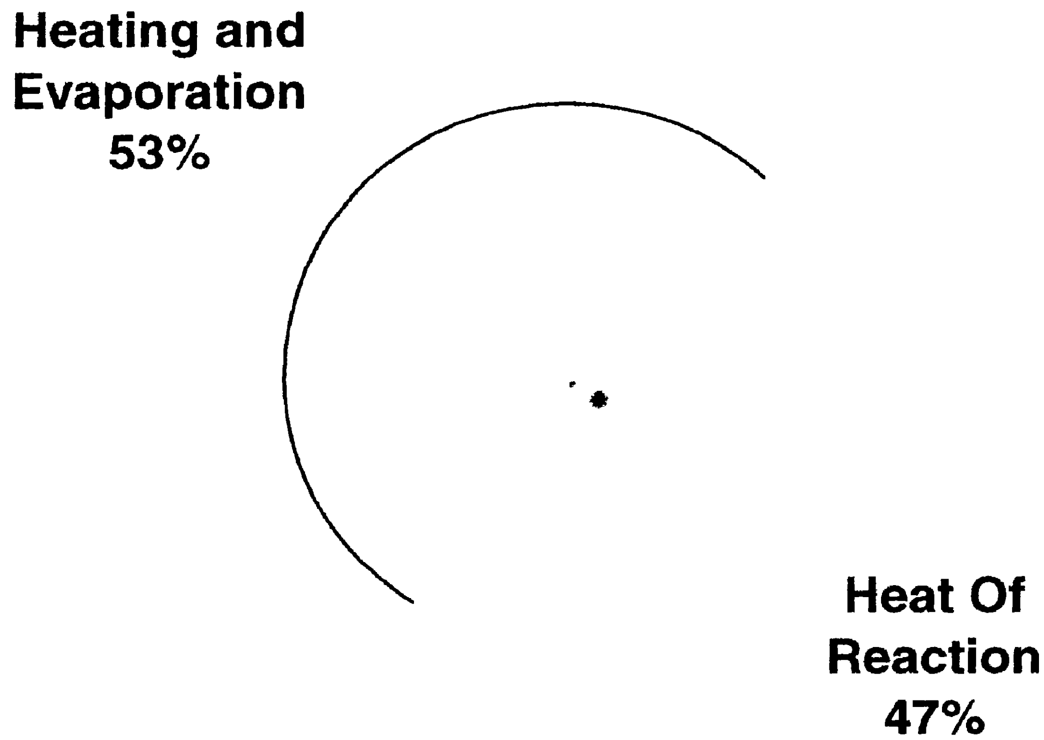
- POWER REQUIRED FOR
  - MECHANICAL GRINDING
  - CONVEYING DUTIES

- FUEL REQUIRED FOR
  - HEAT OF REACTION
  - HEATING AND EVAPORATION

APPLICATION OF PINCH ANALYSIS IN CEMENT INDUSTRY

BASIS : DRY CEMENT PLANT

TYPICAL FUEL USAGE



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PINCH ANALYSIS - STREAM DATA

COLD STREAMS

1. RAW MILL HEATING DUTY
2. WATER EVAORATION DUTY
3. PREHEATER HEATING DUTY
4. HEAT OF REACTION
5. KLINKER HEATING DUTY

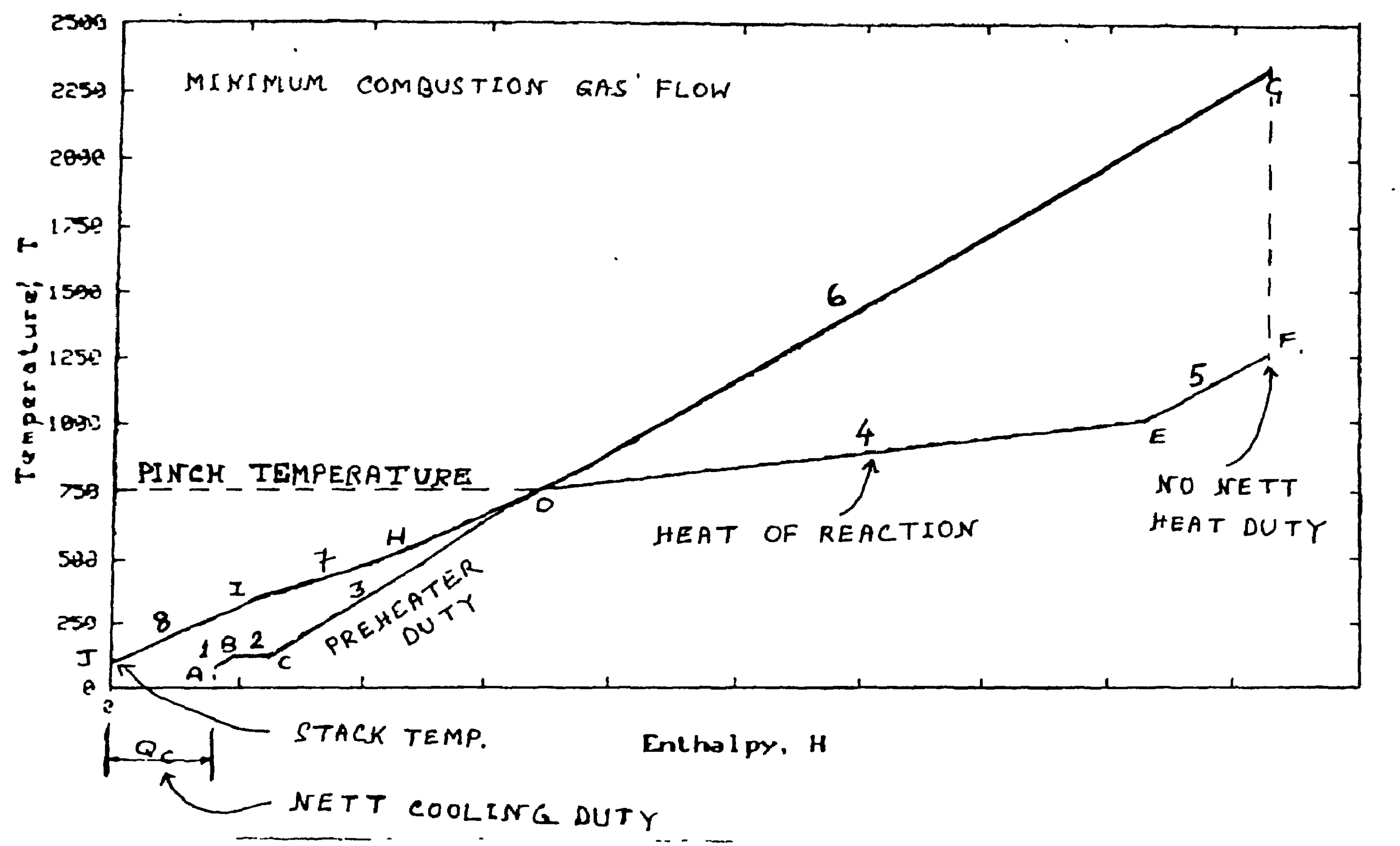
PINCH ANALYSIS - STREAM DATA

HOT STREAMS

6. COMBUSTION GAS HEAT

7. HEATING EFFECT DUE TO RAW MATERIAL CARBON

8. EXIT WASTE GAS HEAT



COMPOSITE CURVES

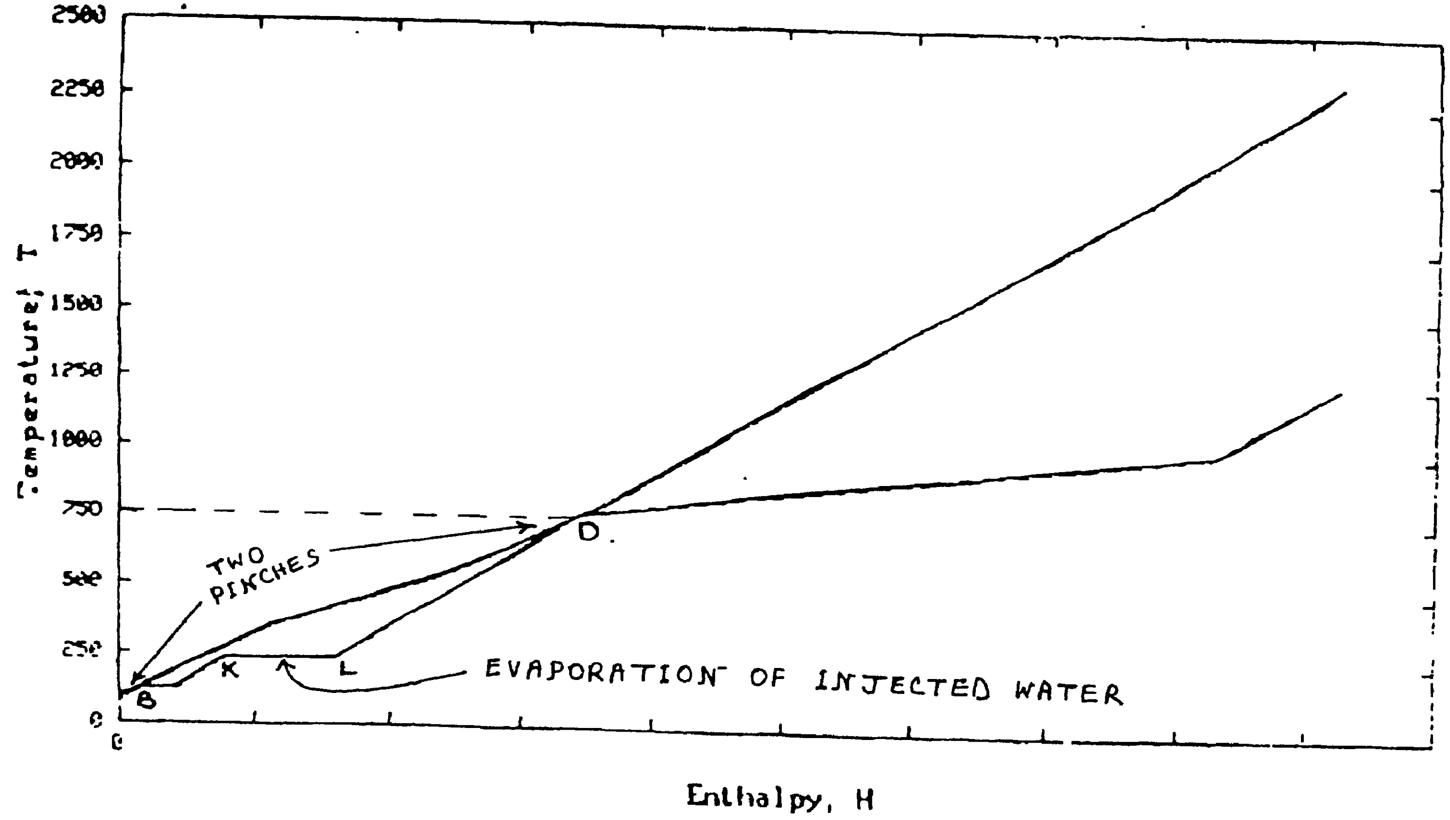
OBSERVATIONS

- PINCH IS CREATED BY HEAT OF REACTION
- PINCH TEMPERATURE IS AROUND 750 °C
- NO HOT UTILITY REQUIRED
- NETT COLD UTILITY REQUIRED

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COLD UTILITY

- INCREASE WASTE GAS STACK TEMPERATURE
  - MAY NOT BE DESIRABLE
- INJECT WATER INTO THE PREHEATER



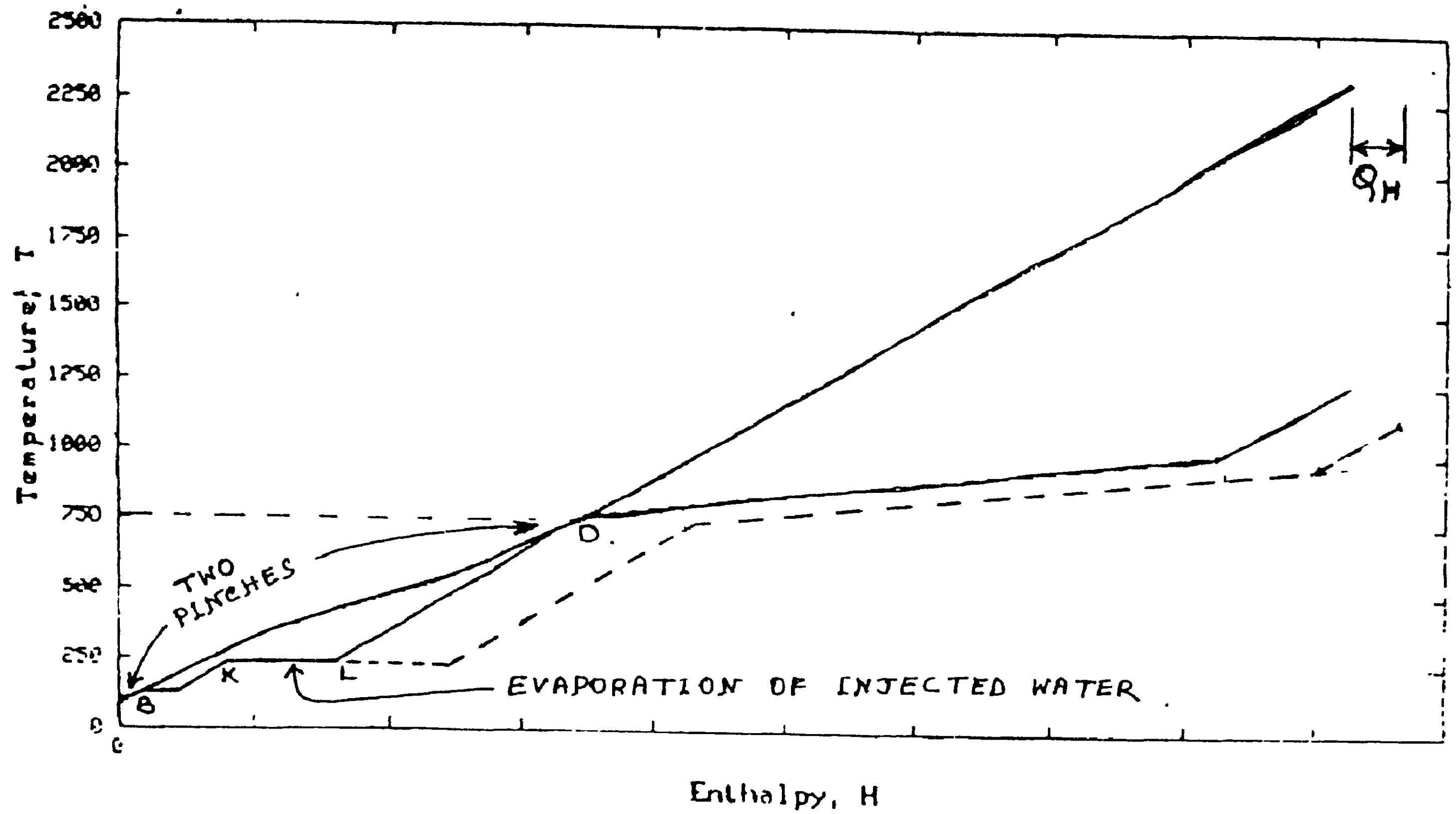
EFFECT OF WATER INJECTION

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EFFECT OF WATER INJECTION

- **SECOND PINCH CREATED AT LOWER TEMPERATURE**
- **AMOUNT OF WATER INJECTION JUST BALANCES THE COLD UTILITY REQUIREMENT**

WHAT IF WATER INJECTION RATE IS RAISED FURTHER ?



EFFECT OF INCREASED WATER INJECTION

EFFECT OF INCREASED WATER INJECTION

- SINGLE PINCH AT A LOWER TEMPERATURE
- HOT UTILITY NOW REQUIRED
- TO BE MET BY INCREASING COMBUSTION GAS RATE
- LEADS TO HIGHER FUEL CONSUMPTION (ABOVE THE MINIMUM)

WATER INJECTION - THRESHOLD VALUE

DEFINITION : MAXIMUM WATER INJECTION RATE AT WHICH NO HOT UTILITY IS REQUIRED (ABOVE MINIMUM COMBUSTION AIR)

DEPENDS UPON :

- CARBON CONTENT OF THE RAW MATERIAL
- WATER CONTENT OF THE RAW MATERIAL

THUS THRESHOLD WILL VARY WITH RAW MATERIAL

SIGNIFICANCE OF THRESHOLD VALUE

- IDEALLY, PLANT SHOULD OPERATE AT THRESHOLD, i.e. SHOULD HAVE TWO PINCH POINTS

- PLANT OPERATING BELOW THE THRESHOLD CONDITION

  THE TOTAL ENERGY CONSUMPTION IS INDEPENDENT OF
  - WATER CONTENT OF RAW MATERIAL
  - CARBON CONTENT OF RAW MATERIAL
  - THE WASTE GAS STACK TEMPERATURE
  - WATER INJECTION RATE
  - THE PREHEATER HEAT LOSSES

- PLANT OPERATING ABOVE THE THRESHOLD CONDITION

  THE TOTAL ENERGY CONSUMPTION DEPENDS ON ALL THE ABOVE FACTORS

PINCH ANALYSIS CONCLUSIONS

- IDENTIFICATION OF CORRECT PINCH LOCATION GUIDES ENERGY CONSERVATION PROJECTS
- EFFORTS SHOULD BE MADE TO OPERATE THE UNIT AT THRESHOLD CONDITIONS
- THRESHOLD CANNOT BE GENERALIZED, NEEDS TO BE ESTABLISHED BY PINCH ANALYSIS

RETROFITTING FOR ENERGY CONSERVATION

1. REDUCE THE WATER INJECTION RATE INTO THE PREHEATER UPTO THE THRESHOLD VALUE

2. IMPROVE COOLER EFFICIENCY

3. REDUCE KILN SHELL LOSSES
   - LOWER INCENTIVE IF PLANT OPERATES ABOVE THRESHOLD

4. REDUCE TEMPERATURE DIFFERENCE IN PREHEATER
   - IMPORTANT ONLY IF PLANT OPERATES BELOW THRESHOLD

PROJECTS LEADING TO REDUCED WATER INJECTION RATE

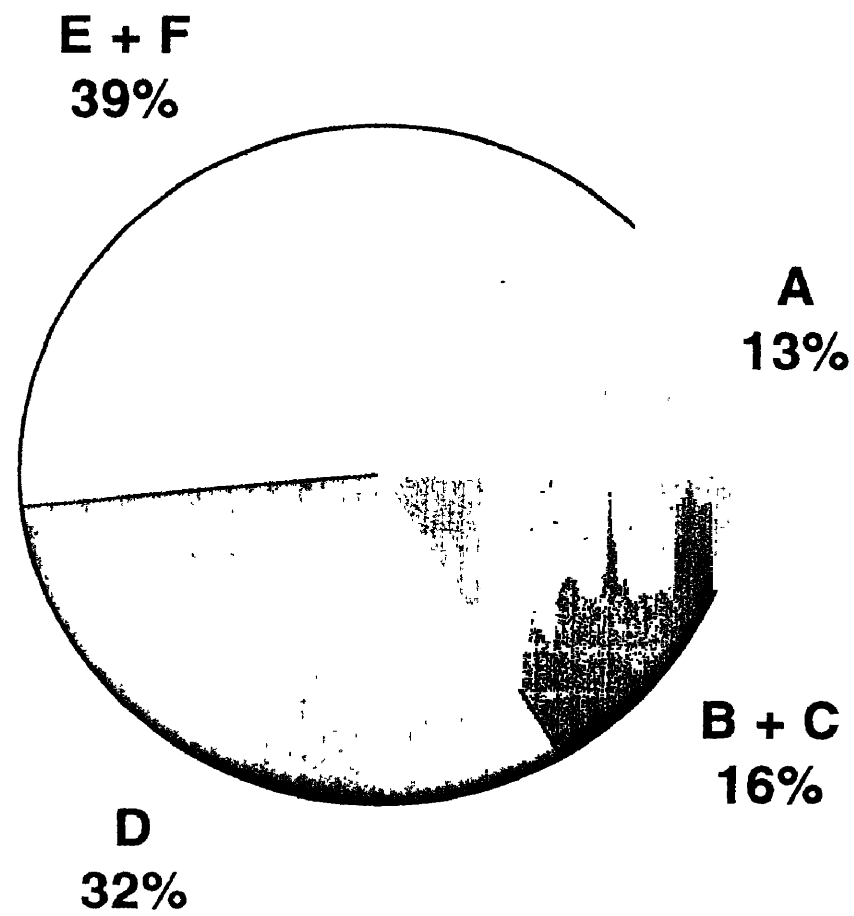
- REDUCE WASTE GAS STACK TEMPERATURE
- IMPROVE WASTE GAS PRECIPITATOR EFFICIENCY
- PREHEAT THE INJECTION WATER BY WASTE AIR FROM THE COOLER

IMPROVEMENT OF COOLER EFFICIENCY

- MAXIMIZE AIR TEMPERATURE TO THE COAL MILL
- MINIMIZE AIR FLOW TO THE COAL MILL, A 10% REDUCTION USUALLY POSSIBLE
- RECYCLE WASTE AIR TO THE HOT END OF THE GRATE COOLER TO INCREASE EFFICIENCY

Retrofit Project Energy Savings

- A : Reduce waste gas stack temperature
- B : Increase air temperature to the coal mill
- C : Reduce air flow rate to the coal mill
- D : Recycle cooler air
- E : Improve waste gas precipitator efficiency
- F : Preheat injection water



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PAYBACK

No.	PROJECT	PAYBACK (MONTHS)
1	Reduce waste gas stack temperature	-
2	Increase air temp. to the coal mill	-
3	Reduce air flow to the coal mill	-
4	Recycle cooler air	-
5	Overhaul waste gas precipitator	20
6	Preheat injection water	12
	OVERALL	**10**

KTI

APPLICATION TO NEW PLANT DESIGNS

MAJOR OBSERVATIONS

- THE SAME PROCESS INTEGRATION CAN BE APPLIED TO NEW PLANTS AT THE PROCESS DESIGN STAGE
- BELOW THE THRESHOLD LEVEL, A WELL DESIGNED SATELLITE COOLER INSTEAD OF A GRATE COOLER OFFERS BOTH CAPITAL SAVINGS AS WELL AS ENERGY SAVINGS
- ABOVE THE THRESHOLD CONDITIONS, A GRATE COOLER IS MORE FAVOURABLE
- USE OF A PRECALCINER OFFERS ENERGY SAVING AS WELL AS CAPITAL SAVINGS DUE TO REDUCED KILN LOSSES

CONCLUSIONS

- PINCH ANALYSIS ESTABLISHES THE THRESHOLD VALUE FOR WATER INJECTION
- PLANT SHOULD BE IDEALLY OPERATED AT THRESHOLD CONDITIONS
- PROJECTS FOR REDUCING ENERGY CONSUMPTION CAN BE IDENTIFIED
- TYPICALLY 21% SAVINGS POSSIBLE
- ATTRACTIVE PAYBACK - LESS THAN 10 MONTHS
- APPLICABLE BOTH FOR RETROFIT AS WELL AS TO A NEW PLANT DESIGN

Energy Conservation in Material Handling

S K Bahal
CIMMCO

ENERGY CONSERVATION IN MATERIAL HANDLING IN CEMENT PLANTS

S.K. Bahal
(Cimmco Birla Limited
D-180, Okhla Industrial Area
Phase I
New Delhi - 110 020)

1.0 INTRODUCTION

In the year 1996-97 the cement produced in the country in large cement plants was about 70 million tonnes against an installed capacity of above 96 million tonnes as on 31/3/1997. The consumption in the same year was about 68 million tonnes, leaving about 2 million tonnes of cement surplus as on 31/3/1997. The current year is no different Because of lack of demand, some of the plants have deliberately cut down their production.

While input costs of the industry are increasing, the realisation is either constant or is lesser because of the glut in the market. Under present highly competitive market situation, Industry has no option but to reduce the cost of production of which power is a major constituent. In most of the plants power accounts for roughly 25% of the total cost of production.

General awareness with regard to necessity of reducing energy consumption is already there in the industry and trend of using power efficient equipments/systems has set in. Initially the emphasis was on main equipments like grinding machines but now the energy conservation in smaller machines and by system optimisation are receiving attention of Engineers/Designers and plant and managers. Material Handling equipments and systems are no exception.

Substantial improvement has been recorded in last about five years in the area of energy conservation. Earlier a plant consuming 100 Kwh/tonne cement of electrical energy and 750 Kcal/kg clinker of thermal energy were considered very efficient plants. But some of the latest plants consume about 80 Kwh/tonne and 690 Kcal/kg of electrical and thermal energy respectively. Effort is to further reduce this.

Table I indicates sectionwise power consumption in one of the operating plants which was commissioned recently. For this plant, client has selected one of the most energy efficient equipments/systems.

2.0 MATERIAL HANDLING E • UIPMENTS

All the equipments which are used for movement of materials and their storages are material handling equipments. Material handling systems are vital links between the main production equipments/systems. List of material handling equipments normally used in cement industry with their general application is given in Table II.

3.0 ELECTRICAL ENERGY CONSUMPTION IN MATERIAL HANDLING EQUIPMENTS

In a large cement plant of say 1.25 million tonne annual capaicty, electrical energy consumption in material handling equipments is in the range of 9 to 15 Kwh/tonne depending on layout design, equipment selection etc. Typical energy consumption of two cement plants is given in Table III. Plant B is comparatively old plant which has 5.61 Kwh/tonne extra consumption in material handling equipments alone. If power tariff is taken @ Rs. 3.00 per Kwh for 1.25 MT plant, 5.61 Kwh/tonne extra consumption would mean Rs. 210 lakhs per annum. This is just to indicate magnitude of savings which can be achieved by properly planning material handling system and equipments.

It may be noted that this saving does not include extra energy consumption in heavy earthmoving equipments which are deployed in Plant 'B' because of inadequate automatic reclaim system.

4.0 CONSIDERATION FOR ENERGY CONSERVATION

4.1 It is most beneficial if all the energy conservation aspects are considered right from the beginning of the project. Though it may be possible to introduce energy efficient equipment/systems at a later stage, but it may not necessarily be optimum solution and cost effective.

4.2 Process Design

Cement is a typical plant which require lifting of material at number of stages e.g lifting from mine bench to crusher hopper, crusher to stockpile top, stockpile to mill hopper and then to raw mill, mill discharge to silo top, silo discharge to PH top and so on. Lifting of material consumes higher energy than horizontal movement. Few meter saving in lifting of material will result in appreciable saving over life cycle of the plant. Process designer should consider this aspect also while designing process equipment/systems.

4.3 Layout Engineering

Layout has a great effect on the energy consumption of material handling equipments. Some of the main aspects which should be considered while preparing layout are given below.

4.3.1 Compactness

A staggered layout will require longer distances of material transport hence higher energy consumption. Attempt should be made to keep the departmental distances as less as possible. But this aspect will conflict with other requirement of plant of proper approaches to all departments for erection and maintenance. It will be the job of the layout engineer to arrive at optimum location of departments satisfying both conflicting situations.

Similarly, from energy conservation point of view, taller layouts are advantageous as compared to longer layouts. In taller layouts, use of gravity flow can be derived.

4.3.2 Use of Natural Gradient

Movement of material against gravity consume more energy compared to horizontal or downward movement. Natural contours of the land where the plant is to be located should be very carefully examined and attempt should be made to use of natural downward gradient towards flow of material.

4.3.3 Rational Movement of Material

For cement making it is required to move material from mine and material received from external sources to the point of finished product loading. Layout engineer should attempt to move the material through shortest path from source to finished product i.e in rational direction. Zig zag movement of material will increase conveying length thus energy consumption.

4.3.4 Optimisation of size of Storages

Too large storages of semifinished materials will call for increase in conveying length hence increase in energy consumption. Optimum size of storages for smooth and continuous operation of the plant should be decided which will depend on capacity of the plant, lead time of receipt of material, sensitivity of material to the plant operation, inventory carrying cost, operating cost etc.

4.3.5 **Proximity of Plant with respect to Mines**

Though the location of plant with respect to the mines will depend on various factors like infrastructre facilities, market etc., attempt should be made to locate the plant as close as possible to the mines.

4.4 **Selection of Equipment**

This is one of the most vital considerations from energy conservation point of view. Various alternatives are available for material movement and storages. It has been seen that energy efficient equipments are invariably costlier. But the selection of equipment should be done on the basis of long term economics.

Apart from selection of type of equipment, it is important that, optimum capacity of the conveyors should be decided keeping in view potential capacity of main production equipments. Too large a capacity will result in higher energy consumption.

Table IV gives department wise options available for selection of material handling equipments. Salient points of each equipment from energy conservation point of view are discussed below.

4.4.1 **Limestone transport from Mine to Crusher**

ROM limestone is essentially transported from Mines to Primary Crusher by means of dumpers. Though transport by dumper is very expensive but there is no alternative to this. Therefore the crusher should be located in such a way that the lead of dumpers is minimum in the long run.

From energy conservation consideration, installation of mobile/semi mobile crusher can be considered in the cases where the dumper lead is likely to increase substantially in future. With mobile crusher, portable belt conveyors are considered which are very energy efficient. However, the capital cost in this case is mostly prohibitive.

4.4.2 **Feeding to limestone crusher**

For this application apron feeder or grizzly feeders are used and there are no viable alternative to this.

4.4.3 **Transportation of crushed Limestone**

Various alternatives are available viz. ropeway, belt conveyor, captive wagons, trucks by road etc. Various factors like terrain, distance, capital cost will affect the selection of mode of transport. From energy conservation and maintenance consideration belt conveyors system is most suited subject to technical feasibility.

4.4.4 Storage of primary crushed material and also of additives is generally done in a conical pile and reclaimed by suitable vibrating feeders. Care should be taken to design suitable reclaim system to leave minimum dead stock. It has been seen that inadequate reclaim system lead to use of bulldozers or payloaders for reclaiming deadstock. This is very inefficient from energy conservation point of view.

4.4.5 For Storage & Reclaim of crushed (secondary) material either preblending stockpile or crane gantry can be selected. For a large cement plant above 600 tpd capacity, gantry storage is not vaible and hence preblending stockpile is resorted to. Various shapes and size for preblending stockpile are possible. All these system are by and large energy efficient.

4.4.6 For transport from stockpile to raw mill hopper and then to raw mill generally belt conveyor system is selected which are energy efficient.

4.4.7 For transportation of raw meal from mill to silos different options are available. Depending on the layout, a combination of airslide and airlift pump or airslide and bucket elevator or penumatic screw pump can be used. Energy conservation wise combination of airslide and bucket elevators are most suitable.

Because of metallurgical limitations of chain, earlier elevators were used upto a max. lift of 25 meters. Therefore, in older plants it would be seen pneumatic conveying was selected which are very energy inefficient. Now chain elevators upto 60 metres height and belt elevators upto 120 meters height are available which are by and large maintenance free. Energy consumption in elevators is very low as compared to penumatic conveying. Table V gives comparative figures of power consumption in elevators (chain & belt) and airlift pump & screw pumps.

Though capital cost of elevators is comparatively higher but life cycle cost of these will workout more economical. In all modern plants elevators are used for this application. In some of the older plants, where the layout feasibility existed, airlift pumps have been replaced by elevators.

For conveying heights more than 60 meters, some of the new plants have opted for two stage chain elevators against belt elevator, mainly because of capital cost considerations.

4.4.8 Raw Meal Blending & Storage is done in silos. Various designs of silos are available. In older plants double deck silos have been installed in which upper deck is used for blending and lower one for storage. From process requirement two sets of double deck silos are required or atleast two blending and one storage silo is required. Apart from very high capital cost, these are energy inefficient equipments.

Now continuous blending cum storage silos are installed in new plants in which single silo can cater to all the requirements. These are energy efficient as compared to double deck silos. In continuous blending cum storage silos also different designs are available, for e.g., conical bottom with multiple discharge and flat bottom silos. Conical bottom silo have advantage of lower energy consumption, negligible dead material and multiple extraction points. Even if one or two extraction points fail, others keep on operating. But the capital cost (Civil Construction Cost) is more than flat bottom silos.

4.4.9 For conveying powdered material to short distances, option between screw conveyors and airslides are available. While screw conveyors can move the material horizontally and at times upwards at some inclination, airslides require gentle downward slope. Airslides apart from being very energy efficient, are cheaper with almost no maintenance cost. The screw conveyors are costlier and maintenance intensive equipments.

4.4.10 For preheater feed application, similar options as per Sl. No. 4.4.7 are available and airslide/elevator combination is most energy efficient.

4.4.11 For transport of hot clinker from cooler, options of deep pan and drag chain conveyors are available. Deep pan conveyors are invariably used in all new plants because of its overall suitability for the application.

4.4.12 For Clinker Storage various options like silo, circular stockpile, longitudinal stockpile are available. Any of the system can be selected based on technoeconomic considerations but care should be taken to design the extraction system in such a way that maximum possible livestock is available in the stockpile. Large quantity of deadstock will necessitate use of bulldozers or payloaders which are very energy inefficient.

4.4.13 For coal unloading from Railway Wagons (open), wagon tipplers are most energy efficient equipmetns. Any other system would require the use of heavy earth moving equipment like dozzer or payloader which are very energy inefficient.

4.4.14 For coal transport and storage, belt conveyors, stacker and reclaimer are most suitable equipments from energy conservation point of view.

4.4.15 For conveying cement from grinding section to silos, combination of belt conveyor and elevator or airslide and elevator or only belt conveyors are most suitable options. Any one of these can be selected depending on the layout of plant and other techno economic considerations.

4.5 Maintenance and Operation

4.5.1 Maintenance of material handling equipments is very important and poor maintenance will contribute towards higher power consumption. Some of the examples of this are given below:

- Jammed carrying and return idlers of belt conveyor will offer higher resistance to belt movement hence higher power consumption.
- Spillage of material at feed point of belt conveyor will at times jam the tail pulley hence higher resistance to movement of belt.
- Jamming - deshaping of rollers of apron conveyor will result in higher power consumption.
- Clogging of air filters for the compressor and blowers will offer higher resistance hence higher power consumption.

4.5.2 Idle running of material handling equipments also contribute in energy consumption. It has been seen that many times belt conveyors, elevators, compressors, blowers etc. run idle after actual conveying has been stopped for some reason. Plant operator has to be vigilant in this respect.

5.0 SPECIFIC POWER CONSUMPTION OF VARIOUS EQUIPMENTS

Specific power consumption of widely used material handling equipments is given in Table VI. This can be used as one of the guidelines for selection of equipments for different applications and layout be designed to suit their installation.

6.0 CASE STUDIES

Some of the important material handling equipments are compared for similar application and the difference in energy consumption vis a vis equipment costs have been quantified. For the equipments selected for case studies the selection is quite obvious. But for equipments where the capital and operating cost are close, a detailed techno-economic analysis taking due weightage for maintenance cost, civil cost etc. would be necessary.

6.1 Caste Study I - Cement Transport (Short distance) from Mill to Storage Silo

Conveying capacity of 300 TPH which correspond to 1.5 MTPA plant has been considered. Two alternatives are compared i.e. a) combination of airslide and bucket elevator and b) combination of airslide and airlift pump. Conveying height is taken as 50 meters. It may be seen from the Annexure I that the additional capital cost in elevator system is paid back within 6 months by the savings in electrical energy consumption.

6.2 Case Study II - Cement Transport (Long distance) from Mill to Silo

In this case also 300 TPH conveying capacity is considered. Two alternatives are compared i.e (a) combination of bucket elevator and belt conveyor and (b) pneumatic screw pump.

From the Annexure II, it can be seen that the additional capital cost in elevator and belt conveyor system is paid back in approx. 3 months.

6.3 Caste Study III - Cement Transport to Short Distance

Conveying capacity of 200 TPH which correspond to 1.0 MTPA plant has been considered. Conveying to a 60 meters distance by (a) screw conveyor and (b) airslide are compared.

Transport of 60 meters distance by a single screw conveyor is not advisable hence two conveyors each of 30m length considered against single airslide.

It can be seen from the annexure that the screw conveyor system is expensive from initial investment as well as operating cost considerations. However, airslides have to be installed necessarily at a gentle downward slope and layout has to be designed to suit this.

7.0 CONCLUSION

From above we can conclude that substantial scope of conserving energy material handling equipments exist. No efforts should be spared in devising schemes to conserve energy which will not only cut down the operating cost of the plant but will also serve the national cause.

TABLE I

ELECTRICAL ENERGY CONSUMPTION IN A RECENTLY COMMISSIONED CEMENT PLANT

SECTION	ENERGY CONSUMPTION IN KWH/TONNE OF CEMENT
Crusher	0.95
Raw Grinding & Blending Silo	21.20
Pyroprocessing	18.24
Coal Grinding & Coal Dosing & Firing	5.13
Cement Grinding	29.0
Others (Packing, Cement Storage & Utilities)	2.00
Total	76.52

TABLE II

LIST OF MATERIAL HANDLING E ● UIPMENT USED IN CEMENT PLANTS AND THEIR APPLICATION

Sl.No.	Material Handling Equipment	Application
1.	Shovels/Hydraulic Excavator	For loading R.O.M into Crusher
2.	Dozer	For Shifting & Stacking of Bulk Material
3.	Dumpers	For transport R.O.M materials to crusher or disposal of overburden
4.	Payloader	For transport & loading the material
5.	Apron Feeder	For conveying & regulating large size of materials to short distances
6.	Grizzly Feeder	For conveying & regulating large size of materials to short distances
7.	Stacker	For stacking material in a defined pile
8.	Scraper Reclaimer	For reclaiming material from stockpile at ground level.
9.	Belt Conveyors	For transport the coarse/fine material to longer distance upto inclination 18°
10.	Weigh Feeder	For regulated feed from under the bin/hopper
11.	Vibrating Feeder	For regulated feed from below hopper/bin, stockpiles
12.	Rotary Feeder	For extracting fine material without disturbing the system pressure
13.	Chain Feeder	For uniform and controlled feed from under the hopper/bin
14.	Screw Feeder	For uniform and controlled feed from under the hopper/bin
15.	Drag Chain Conveyor	For horizontal or inclined transport of Bulk material (max 20°) . Conveyor can withstand temperature upto 350 °C.
16.	Screw Conveyor	For horizontal or inclined (upto 8°) transport of bulk material. Length upto 30m max.
17.	Bucket Elevator	For Vertical transport of coarse (upto 150mm) and fine material.
18.	Deep Pan Conveyor	For transport hot bulk material in combined horizontal and inclined (max. 60°) direction to large distance.
19.	Airslide	For transport fine material with penumatic system. Gentle downwrd inclination is essential.
20.	Airlift	For vertical transport through pipe with help of compressed air.
21.	Screw Pump	For conveying fine material horizontally and vertically through pipe with help of compressed air
22.	Dense phase Conveyor	- do -
23.	Wagon/Truck Loader	For transport and stacking packed bag cement in wagon/truck
24.	Wagon Trippler	For unloading bulk material from wagon
25.	Truck Trippler	For unloading bulk material from truck

TABLE III

SPECIFIC POWER CONSUMPTION (KWH/TON CEMENT) OF MATERIAL HANDLING E•UIPMENTS IN TWO TYPICAL PLANTS

Sl No	Department	Plant A		Plant B	
		Specific Power Consumption in KWH/T	Equipment	Specific Power Consumption in KWH/T	Equipment
1.	Limestone Crushing upto Preblended Stockpile	0.32	Apron Feeder Belt Conveyor Stacker Belt	0.35	Grizzly Feeder Belt Conveyor Stacker Belt
2.	Limestone Stockpile to Raw Material Grinding Unit	0.24	Reclaimer Belt Conveyor	0.24	Reclaimer Belt Conveyor
3.	Raw Material Grinding and Blending & Storage	3.0	Weigh Feeder Bucket Elevator Belt Conveyor Screw Conveyor Airslide Conical Silo	4.8	Weigh Feeder Bucket Elevator Belt Conveyor Airslide Airlift Double Deck Silo
4.	Blending Silo Extraction & Preheater Feed	1.28	Blower Airslide Bucket Elevator	2.5	Blower Airslide Airlift
5.	Clinker Transport, Storage & Transport to Grinding Unit	0.6	Pan Conveyor Belt Conveyor	1.0	Drag Chain Conv. Pan Conveyor
6.	Clinker Grinding & Cement Transport to Cement Silo	1.4	Weigh Feeder Belt Conveyor Airslide Bucket Elevator	2.95	Weigh Feeder Belt Conveyor Airslide Screw Pump
7.	Cement Silo Extraction, Packing Plant, Truck/Wagon Loading	0.9	Blower Bucket Elevator Airslide Belt Conveyor Truck/Wagon Loader	1.1	Compressor Bucket Elevator Airslide Belt Conveyor Truck/Wagon Loader

Sl No	Department	Plant A		Plant B	
		Specific Power Consumption in KWH/T	Equipment	Specific Power Consumption in KWH/T	Equipment
8.	Coal Unloading to Coal Stockpile	0.25	Wagon Trippler Apron Feeder Belt Conveyor Stacker Belt	0.25	Wagon Trippler Apron Feeder Belt Conveyor Stacker Belt
9.	Coal Stockpile to Coal Mill Hopper	0.2	Reclaimer Belt Conveyor	0.2	Reclaimer Belt Conveyor
10.	Coal Grinding Unit & Coal Feed to Kiln & Pyroclone	1.1	Chain Feeder Screw Conveyor Pfister Pump	1.5	Chain Feeder Screw Conveyor Screw Pump
11.	Gypsum & Additive Handling	0.06	Apron Feeder Belt Conveyor	0.07	Apron Feeder Vibrating Feeder Belt Conveyor
	Total	9.35		14.96	

TABLE IV

DEPARTMENT WISE OPTIONS OF MATERIAL HANDLING EQUIPMENTS

Sl.No.	Department	Option I	Option II	Option III	Option IV
1.	Mining Equipment	Shovel, Loader, Dozer, Dumpers	Hydraulic Elevators		
2.	Feeding to Limestone Crusher	Apron Feeder	Grizzly Feeder		
3.	Transport of Crushed Limestone	Belt Conveyor	Ropeway	Captive Railway Wagons	Trucks
4.	Storage of primary crushed material & additives	Conical pile with vibrating feeder & belt conveyor	Ground storage with Payloader & Belt Conveyor		
5.	Crushed Limestone Storage	Longitudinal stockpile with Stacker & Reclaimer	Circular Stockpile with Stacker & Reclaimer	Crane Gantry	
6.	Stockpile to Raw Mill Hopper & to Mill	Belt Conveyor			
7.	Raw Meal Transport from Mill to Silo	Airslides, Bucket Elevator	Airslides, Airlift	Pnuematic Screw Pump	
8.	Blending & Storage Silo	Continuous Blending cum Storage Silo with conical bottom	Double deck Blending/Storage Silo	Continuous Blending with Flat Bottom	

Sl.No.	Department	Option I	Option II	Option III	Option IV
9.	E.S.P Dust Transport	Screw Conveyor Chain Conveyor Bucket Elevator	Screw Conveyor Bucket Elevator	Screw Conveyor Screw Pump	
10.	Preheater Feed	Airslide Bucket Elevator	Airslide Airlift	Airslide Screw Pump	
11.	Hot Clinker Transport	Deep Pan Conveyor	Drag Chain Conveyor Deep Pan Conveyor	Apron Bucket Conveyor	
12.	Clinker Storage	Conical Stockpile	Clinker Silo	Longitudinal Stockpile	
13.	Clinker Transport from Stockpile	Belt Conveyor	Deep Pan Conveyor		
14.	Cement Transport to Cement Silo	Airslide, Bucket Elevator	Bucket Elevator Belt Coneyor	Airslide, Airlift	Penuamtic Screw Pump
15.	Cement Silo	Conical Bottom	Flat Bottom		
16.	Cement Silo to Packing Plant	Airslide, Bucket Elevator			
17.	Packing Plant to Bag Loading	Belt Conveyor Truck/Wagon Loader			
18.	Cement Silo to Ship Loading	Covered Belt Conveyor	Screw Pump		

TABLE V

COMPARISON OF POWER CONSUMPTION IN ELEVATORS, AIRSLIFT PUMPS & SCREW PUMPS FOR TRANSPORT OF CEMENT FOR CONVEYING HEIGHT OF 100M

CAPACITY IN TPH	SHAFT POWER IN KW			
	Belt Bucket Elevator	Chain Bucket Elevator	Airlift Blower	Screw Pump & Compressors
150	58	44 x 2 = 88	230	320
200	77	58 x 2 = 116	248	358
250	96	65 x 2 = 130	352	472
300	115	79 x 2 = 158	460	600
400	146	98 x 2 = 196	568	369 x 2 = 738

TABLE VI

SPECIFIC POWER CONSUMPTION IN VARIOUS EQUIPMENTS

Example

Conveying Capacity - 300 t/hr
Material - Cement
Conveying Distance - 50 m

Sl.No.	Equipments	Specific Power Consumption in Kwh/t *
1.	Horizontal Screw Conveyor	0.55
2.	Horizontal Chain Conveyor	0.25
3.	Horizontal Belt Conveyor	0.03
4 (a)	Vertical Bucket Elevator - Chain Type	0.27
(b)	Vertical Bucket Elevator - Belt Type	0.20
5.	Airslides (Gentle Downward)	0.04
6.	Airlift (Vertical Conveying)	1.0
7.	Screw Pump (Horizontal & Vertical Conveying)	1.4
8.	Dense Phase System (Horizontal & Vertical Conveying)	0.6

* The figures given are only indicative and should not be taken as the basis for equipment selection.

For equipment selection actual parameters should be considered along with other costs like civil construction, maintenance etc.

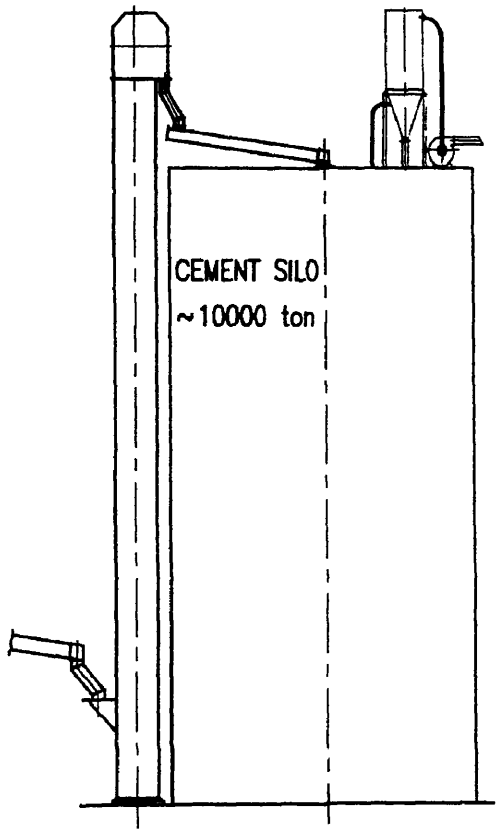
SUB : CEMENT TRANSPORT FROM GRINDING UNIT TO SILO LOCATED NEAR TO CEMENT MILL

DATA : CONVEYING CEMENT 300 t/h
HORIZONTAL DISTANCE = 5m
VERTICAL DISTANCE = 50m

OPTION 1

CEMENT TRANSPORT WITH AIRSLIDE & BUCKET ELEVATOR

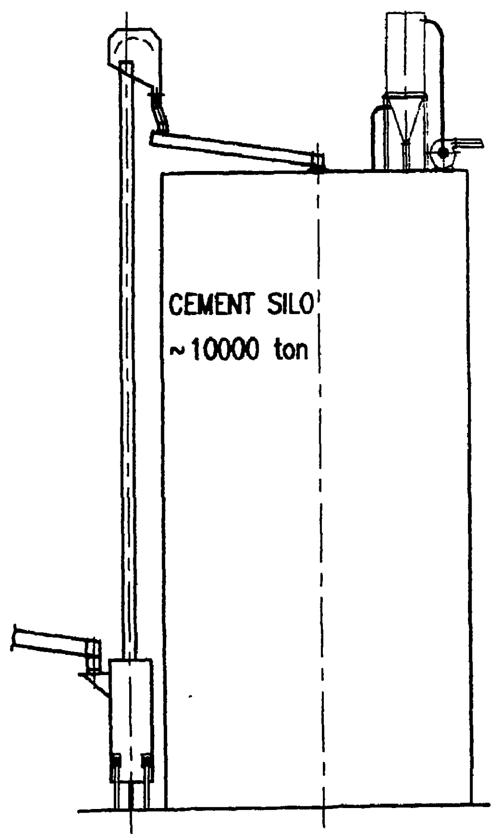
SN	LIST OF EQPTS.	SPECS	POWER CONS kW	COST Rs. IN LACS
01	AIRSLIDE	SIZE: 500x 5m Lg	2.0	0.30
02	BUCKET ELEVATOR	CTC: 56m	80.0	34.0
03	AIRSLIDE	SIZE: 500x 10m Lg	4.0	0.6
04	BAG FILTER, FAN & ROTARY AIRLOCK	CAP: 8000m3/hr	11.0	1.3
TOTAL			97 kW =0.323 kWh/ton	36.2



PTION 2

CEMENT TRANSPORT WITH AIRSLIDE & AIRLIFT

SN	LIST OF EQPTS.	SPECS	POWER CONS kW	COST Rs. IN LACS
01	AIRSLIDE	SIZE: 500x 5m Lg	2.0	0.30
02	AIRLIFT BLOWER & AIRLIFT	CAP: 15000m3/hr	265.0	17.0
03	AIRSLIDE	SIZE: 500x 10m Lg	4.0	0.60
04	BAG FILTER, FAN & ROTARY AIRLOCK	CAP: 20000m3/hr	21.0	3.0
TOTAL			292 kW =0.973 kWh/ton	20.9

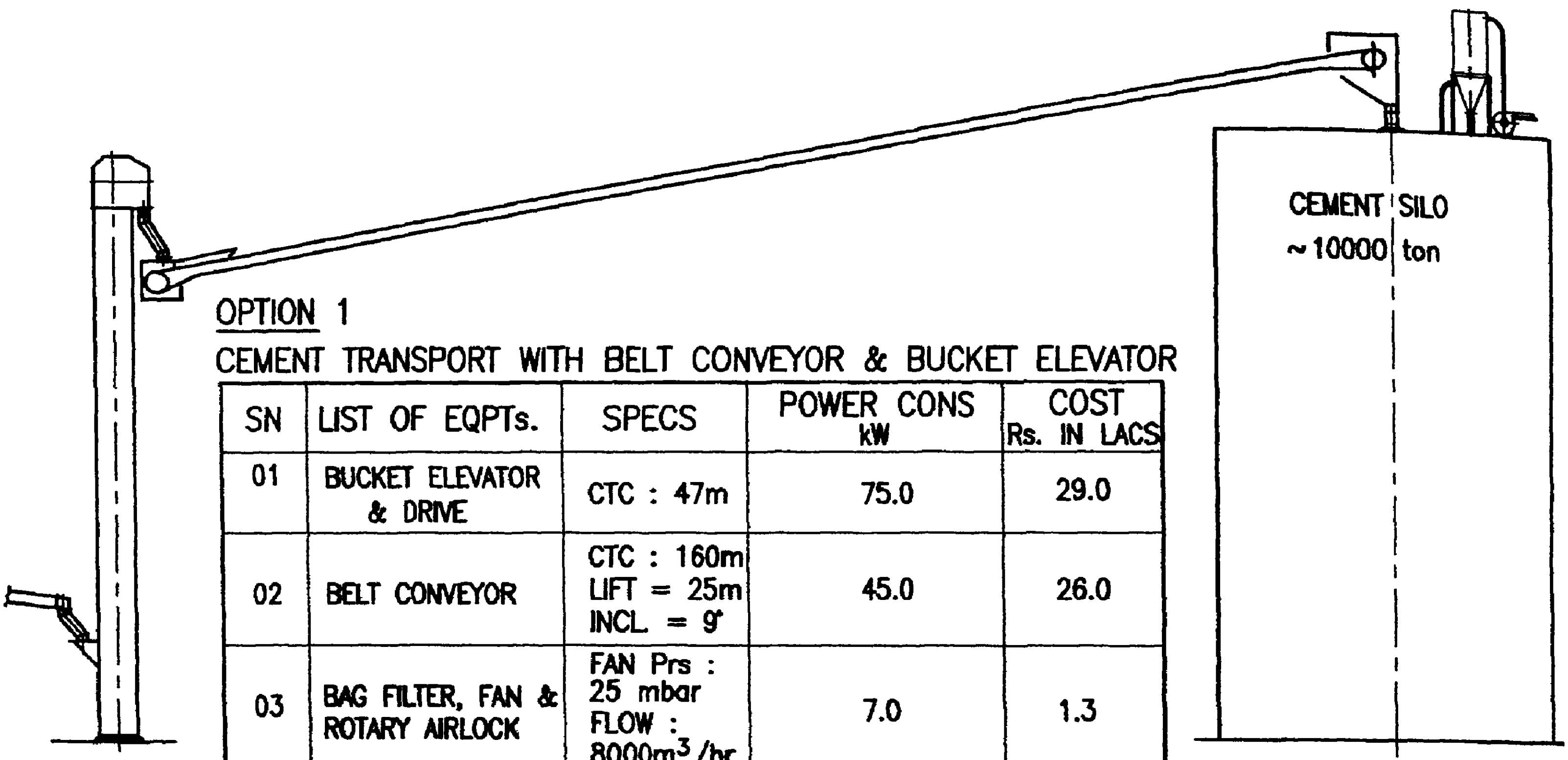


FERENCE IN CAPITAL COST 36.2 − 20.9 = Rs.15.3 LACS
VING IN ENERGY COST @ Rs.3.00 PER kwh FOR 1.5 MILLION TONNE PLANT.
650 x 15 x 3 = Rs. 29.25 LACS
Y BACK PERIOD = APPROX. 6 MONTHS. HENCE OPTION-1 IS ECONOMICAL.

CASE STUDY 2 ANNEXURE

SUB : CEMENT TRANSPORT FROM CEMENT GRINDING UNIT TO SILO LOCATED AT LONG DISTANCE

DATA : CONVEYING CAPACITY 300 t/h
HORIZONTAL DISTANCE = 160m
VERTICAL DISTANCE = 50m



OPTION 1

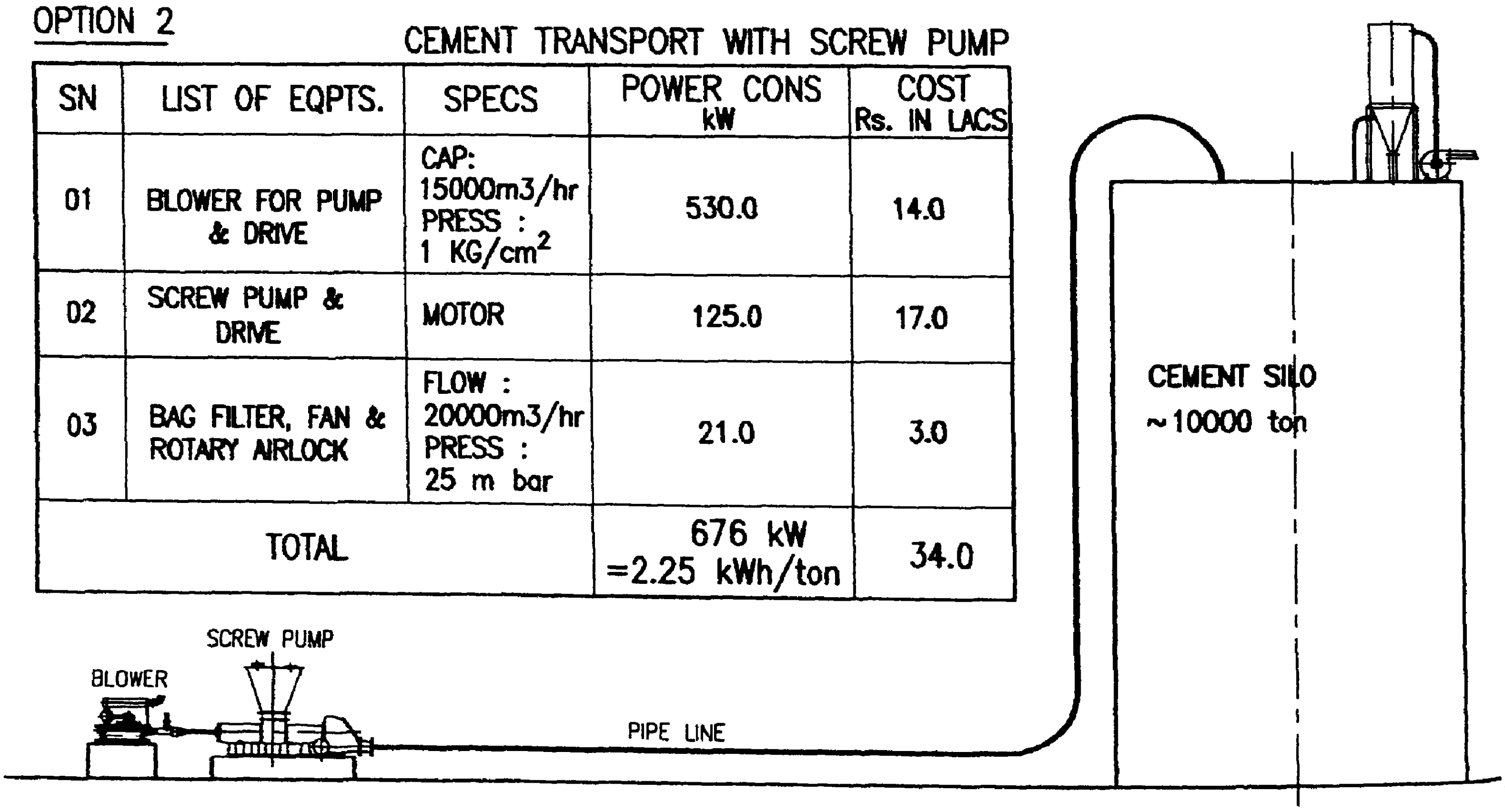
CEMENT TRANSPORT WITH BELT CONVEYOR & BUCKET ELEVATOR

SN	LIST OF EQPTs.	SPECS	POWER CONS kW	COST Rs. IN LACS
01	BUCKET ELEVATOR & DRIVE	CTC : 47m	75.0	29.0
02	BELT CONVEYOR	CTC : 160m LIFT = 25m INCL = 9°	45.0	26.0
03	BAG FILTER, FAN & ROTARY AIRLOCK	FAN Prs : 25 mbar FLOW : 8000m^3/hr	7.0	1.3
TOTAL			127 kW =0.42 kWh/ton	56.3

OPTION 2

CEMENT TRANSPORT WITH SCREW PUMP

SN	LIST OF EQPTS.	SPECS	POWER CONS kW	COST Rs. IN LACS
01	BLOWER FOR PUMP & DRIVE	CAP: 15000m3/hr PRESS : 1 KG/cm^2	530.0	14.0
02	SCREW PUMP & DRIVE	MOTOR	125.0	17.0
03	BAG FILTER, FAN & ROTARY AIRLOCK	FLOW : 20000m3/hr PRESS : 25 m bar	21.0	3.0
TOTAL			676 kW =2.25 kWh/ton	34.0



DIFFERENCE IN CAPITAL COST 56.3 – 34.0 = Rs.21.3 LACS

SAVING IN ENERGY COST @ Rs.3.00 PER kwh FOR 1.5 MILLION TONNE PLANT

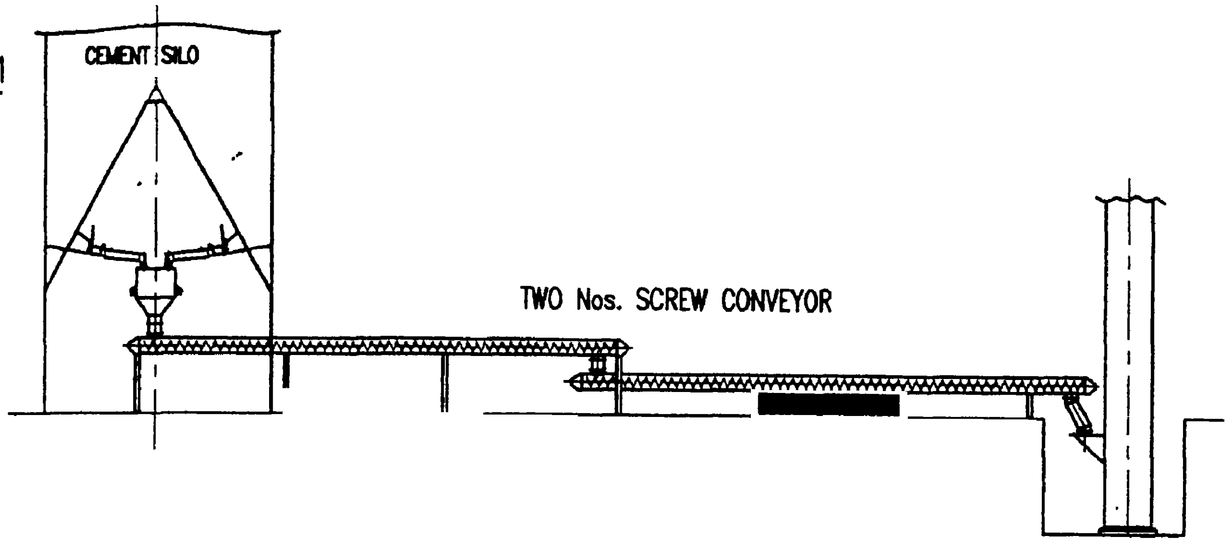
~~1.83 x 15 x 3 = Rs. 82.35 LACS~~

PAY BACK PERIOD = APPROX. 3 MONTHS. HENCE OPTION-1 IS ECONOMICAL.

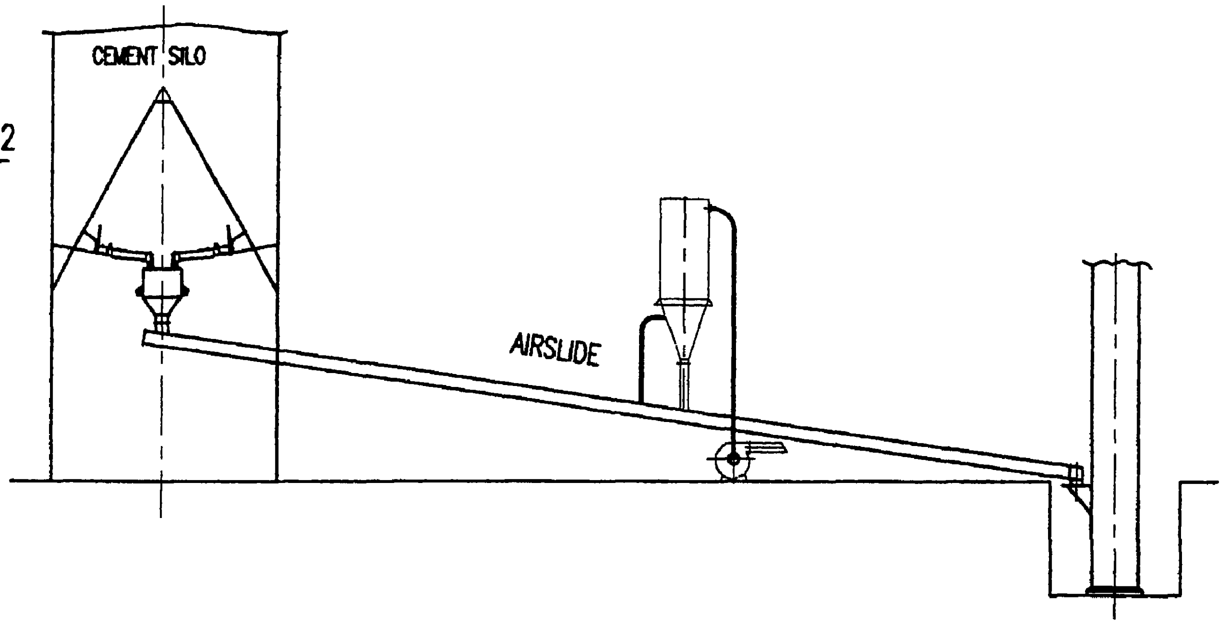
SUB : CEMENT TRANSPORT WITH SCREW CONVEYOR OR AIRSLIDE

DATA : TRANSPORT RATE = 200 t/h
HORIZONTAL DISTANCE = 60m

OPTION 1



OPTION 2



	SN	LIST OF EQPTS.	SPECS	POWER CONS kW	COST Rs. IN LACS
OPTION - 1	01	SCREW CONVEYOR	DIA = 0.8m CTC = 30m QTY = 2Nos.	130.0	15.0
				0.65 kWh/ton	
OPTION - 2	02	AIRSLIDE BLOWER	CAP : $70m^3/min$ PRESS : 63 m bar	12.0	8.0
	03	BAG FILTER, FAN & ROTARY AIRLOCK	CAP : $5000m^3/min$ PRESS : 25 m bar	6.5	
	TOTAL			18.5 =0.10 kWh/ton	

EQUIPMENT COST AS WELL AS OPERATING COST IS SUBSTANTIALLY LESS IN CASE OF AIRSLIDES.

Energy Conservation in Grinding and Crushing Systems

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Energy Conservation in Crushing and Grinding Operations

1.0 Introduction

Energy costs account for nearly 50% of the total manufacturing costs in the manufacture of cement, and share of electrical energy is estimated at to 15-20%. Nearly two-thirds of the electrical energy is consumed for size reduction operations, that is crushing and grinding. Rapidly increasing power tariffs on one hand and requirement for higher flexibility with regard to product design and quality to meet the customers specific needs on the other, have necessitated very significant developments in the area of comminution.

Size reduction is a basic unit operation of chemical engineering. Across the chemical process industries, solids are crushed, ground, pulverized and milled. The purpose is typically to prepare them for further processing e.g. reaction, extraction or mixing with other solids. In the process of cement manufacture, size reduction is one of the principal operations, which is required for the preparation of raw materials and coal for the pyroprocessing operation and for making the finished product from clinker. Size reduction in cement industry is effected generally in two stages, that is crushing followed by grinding. Crushing denotes size reduction to a particle size suitable for feeding to the grinding operation. Depending on the grinding equipment used, crushing is taken to mean the reduction of particle size to between 150 and 20 mm. In the subsequent grinding operation the particles are reduced to a size generally below 0.2 mm. Crushing and grinding operations are highly energy intensive operations which consume about 40% of the total energy consumed in cement production. It is essential that these systems should operate at highest possible efficiency, as even small improvement of the efficiency of the process may lead to a considerable saving in energy cost and consumption. Recently concerted efforts were made to upgrade/improve/optimize these operations, by taking into account all aspects of process parameters which would go a long way towards conserving energy. Energy savings in size reduction operations can be brought about in three ways.

- By selection of appropriate equipment/circuit
- By utilizing advanced grinding systems and materials
- By day-to-day mill optimization by suitable adjustment of process parameters.

2.0 Size reduction theories

The three main size reduction theories which have received varying degrees of acceptance are

- Rittinger theory-that the work input is proportional to the new surface produced or inversely proportional to the product size.
- Kick theory-which assumes work input to be proportional to the reduction in volume of the particles.
- Bond theory-which is based on the assumption that work input is inversely proportional to the square root of the diameter of the product particles.

A comparison of the three different comminution theories is shown in **figure 1.** From this we can say that Rittenger's law holds good for finer grinding and Bond's law is widely used for grinding from about 25 mm to 100 microns. Kick's law holds good for crushing only.

3.0 Selection and merits of various crushers

Selection of crushers depends on various aspects like material characteristics, reduction ratios, etc., In cement industry, the factor of paramount interest for performance is the ration of reduction. The ratios of reduction for various types of crushers according to the major force applied is given at **figure 2** and are to be regarded only as technically approximate values since the reduction ratio obtained in practice, to a higher degree is a function of the wear that may be economically acceptable. The price of the crusher is directly proportional to the maximum feed size rather than its rate of production. Hence, it is evident, that except at very large production volumes, a lot may be saved by keeping down the top size of the feed. Hammer and impact crushers have the largest reduction ratios and whenever suitable they are preferred.

Overall cost of these units is usually low since they are often one-stage installations. A first hand choice of the crushers depending upon the feed properties of compressive strength, abrasiveness and stickiness can be made from **figure 3.** Jaw crushers come in two versions, one with a linear movement (double toggle) and one with an elliptical movement (single toggle). The later is more sensitive to wear than the double toggle but gives a better reduction ratio. The double toggle is used for either extremely hard and abrasive rocks or for primary reduction of big boulders. In both cases, the angle between the jaws is 18 to 20° and adjustments are normally not possible. Angles greater than 20° should be chosen with care since chocking may easily occur. The ratio of reduction is a function of both the angle between the jaws and the jaw length. The jaws are usually ribbed and the pattern of ribs are chosen in accordance with feed properties. The double toggle crusher is more sensitive to sticky feed since the only downward force on the feed is gravity.

Gyratory and cone crushers are used for primary and secondary crushing respectively. These are highly suitable for abrasive materials. Gyratory crushers are generally used for large capacities especially more than 80 tph which justifies its cost. However these crushers should not be used with sticky materials. Hammer crushers have a high reduction ratio. Often they may reduce run of mine rock to tube mill feed in one step. Materials more abrasive than 10 g/t are usually not suited to be crushed in this type of crusher and the maximum allowed compressive strength is typically 200 MPa. When feeding sticky materials, the rate of production decreases and power consumption increases. Impactors are similar to hammer crushers but crushing is performed not only by direct action of the blow bars but also by hurling the particles against the anvil. The crusher has no outlet grate and hence the product size distribution is not

well controlled. Impactors are not so sensitive to abrasive materials as the hammer crushers. The reason is that there is more steel to wear away. Hammer and impact crushers may also be used as driers by adding hot air.

4.0 Grinding systems

Fine grinding is required in cement manufacture for raw materials, fuel and cement clinker. During the last 20 years, throughput rates and grinding equipment sizing have increased significantly. An accompanying effect of a great number of mechanical improvements and advancement of process control, thereby reducing the energy consumption substantially. Experience over the past few years has shown that the choice of an optimum grinding system is influenced by various factors such as:

- Meeting quality and environmental requirements
- Energy efficient operation
- Lower investment costs
- Reliability and flexibility

The factors that influence the grinding system performance are:

- Material characteristics
- Mill construction
- Process variables

The various types of grinding systems that are being used for the grinding purpose are given below and shown in **figure 4.**

- Conventional tube mill
- Tube mill with a pregrinding unit which could be a roller press/vertical shaft impactor
- Roller press in finish grinding mode
- Vertical roller mill

5.0 Latest trends for energy conservation in grinding systems

5.1 Raw material grinding

For grinding of raw materials the vertical roller mill (VRM) can be generally considered the most economical and efficient system offering energy savings of 35% over the conventional ball mill especially with recent improvement in VRM technology such as high efficiency dynamic separators, external recirculation systems and adjustable nozzle rings. All these improvements are

being incorporated on almost every new system being installed due to the large savings in power consumption that can be realized. Some installations have been built recently featuring a roll press (RP) in closed circuit with a separator and a disagglomerator with mechanical/pneumatic recirculation of the material to the separator. This system has 5-15% lower power consumption than a VRM but is more complicated to operate and maintain. Roller wear has also been a recurring problem. A new grinding system-the horizontal roller mill has recently been developed which combines the reliability of the ball mill with the low power consumption of the roll press while being less complicated to operate and maintain than a VRM. A comparison of the various systems is presented in **Table 1.**

In Indian plants, where raw material drying is usually required, the VRM is the best option. Roller Press systems are not in wide use and sufficient operating data on long term performance is not yet available. The horizontal roller mill is as yet unproven with the first large installations only now being built. The horizontal ball mill is essentially outdated and economical VRMs can be built even for very small capacities such as 50 TPH.

5.2 Coal grinding

The VRM or vertical ball mill (e.g. Babcock E-Mill) is best suited for coal grinding, combining high drying capacity with low power consumption. Use of a Roller Press for coal grinding would necessitate the use of a separate dryer for drying and the overall economics are not attractive.

5.3 Cement grinding

Cement grinding technology is centered around the roller press and high efficiency separators. Various configurations of roller press, ball mills and separators are in use for cement grinding applications. A Roller Press operating in closed circuit with a high efficiency separator is the most energy efficient system available with the power consumption being only 70-75% of the traditional close circuited ball mill. The only problem is that the very close Particle Size Distribution (PSD) tends to cause abnormally high water requirements for the ground cement. Hence it may be necessary to recirculate part of the cake back to the Roller Press to widen the PSD even though this will result in a slight increase in the power consumption. Unfortunately due to the high capital cost, Roller Press technology is not viable for small plants. An extremely promising and cost effective development is the use of a VRM for cement grinding. A VRM with inbuilt high efficiency separator is a popular configuration for cement grinding in Japan with power consumption levels matching that of the Roller Press and much better life of the wear elements. The horizontal roller mill in close circuit is a new development which can be used for cement grinding. Typical levels of power consumption for various cement grinding configurations are given in **Table 2.** In India horizontal ball mills with high efficiency separators continue to

be popular, in part due to problems with roller wear and refacing in Roller Press units. However, with improved roller technology and the large savings in power consumption that can be realized, Roller Presses or VRMs will be increasingly used in the large plants. In small plants the most cost effective solution appears to be a small VRM as a pregrinding unit ahead of a ball mill.

6.0 Case study

The potential for saving energy in case of cement grinding is considerable and a wide range of processes and equipment for cement grinding are available today making the requirement of indepth expert discussions to ultimately select a system. A practical case study of modern cement grinding installation and the results of commissioning of finish grinding system achieved is given in following section.

6.1 Grinding concept

Kalyanpur Cements Limited (KCL), which is a HOLDERBANK group company has installed a new dry process line of 1650 TPD capacity at their Banjari Works in Bihar. KCL with a target to reduce the clinker/cement ratio has decided to produce Portland Slag Cement. Out of the available two alternatives of combined grinding and separate grinding of slag and clinker, separate grinding was chose due to its various advantages.

6.2 Technical details

The technical details of the cement grinding plant installed at KCL are as under:

6.2.1 Slag drying/grinding

The equipment selected for slag grinding is Roller Press with a dynamic separator as finish grinding system. The moist slag is pre-dried in a flash drier to 1.5% moisture. Pre-dried slag is fed to the Roller Press along with gypsum and will pass through a disagglo-merator and separator. The separator is equipped with hot gas connection for final drying of material before storing in silo. The slag Drying/Grinding concept is shown in **Fig.5**

6.2.2 Clinker grinding

Due to the availability of the existing tube mill, a two stage grinding system having roller press as a pregrinder has been chosen. Clinker and gypsum are ground in a roller press with a separator and this product is then finish ground in a tube mill to the required fineness. The Clinker Grinding concept is shown in **Fig 6.**

6.2.3 Cement mixing plant

A double paddle flight conveyor is used for the mixing of ground slag and ground clinker components. Mixing homogeneity is ensured to a correct cement compositions in each 0.5 kg of blended cement. The Cement Mixing concept is shown in **Fig 7.**

6.3 Commissioning results

The clinker grinding system at KCL has been commissioned as a single stage i.e. Roller press in finish grinding mode along with High Efficiency Separator for OPC grinding, even though the plant has envisaged the use of 2 stage grinding process. The test results of the Ordinary Portland Cement (OPC) 33 Grade Produced in finish grinding mode are comparable with the International Standards and are shown in **Table 3.** The clinker grinding system (OPC) is designed for a capacity 100 t/h in 2 stage grinding. Since the operation of the system is in single stage the capacity has come down to 65-75 tph. The operating parameters and the power consumption achieved during finish grinding mode are as given in **Table 4.** The following can be concluded on the commissioning results obtained from Kalyanpur Cements Limited.

- The grinding concept adopted at KCL is excellent and energy efficient.
- Cement Grinding in Roller Press in finish grinding mode is the most energy efficient and future grinding concept
- The quality of the cement produced in finish grinding system is comparable with the world standards.
- Low investment and operating costs.

7.0 Conclusions

The energy cost as a percentage of manufacturing cost which was 20-25% in 1980's has presently increased to upto 50%. Hence a kajor area for cutting costs and increasing profits in cement industry is through energy conservation. With the every increasing fuel prices and power tariffs, the need to conserve energy becomes all the more important. To achieve this, proper selection equipment, maintenance and operation is required. Size reduction is one of the principal operation of cement manufacture. Crushing and grinding operations are highly energy intensive, which consumes about 4% of the total energy consumed in the cement manufacture. In the crushing single stage crushing with increasing utilization of crusher along with interlocking of the auxillaries with main drive will save considerable energy. For grinding vertical roller mill and roller press clearly advantage for other systems. The concept of cement grinding adopted at Kalyanpur Cement Limited is energy efficient which can save upto 3% of energy as compared with conventional systems as can be seen from the case study presented above. It is advisable that this concept for cement grinding is followed by more and more industries in order to save precious energy.

Table 1. **Comparison of raw grinding circuits**

System	Power consumption
VRM	10%
Ball mill	150%
RP with mechanical recirculation	85%
RP with pneumatic recirculation	95%
Horizontal roller mill	85%

VRM - Vertical Roller Mill

RP - Roller Press

Table 2. Comparison of cement grinding circuits

System	Power Consumption
RP in closed circuit	66%
RP in closed circuit + BM in closed circuit	71%
RP in closed circuit + BM in open circuit	77%
RP in pregrinding mode + BM in closed circuit	80%
VRM in pregrinding mode BM in closed circuit	80%
VRM in closed circuit	69%
HRM in closed circuit	72%
BM in closed circuit	91%
BM in open circuit	100%

RP - Roller Press

BM - Ball Mill

VRM - Vertical Roller Mill

HRM - Horizontal Roller Mill

Table 3. Comparison of test results

S No	Physical requirements	BS12 (UK)	ASTM C-150 (USA)	IS 269 (India)	KCL test results
1.	Compressive strength kg/cm2 (minimum)				
	3 days	133	127	160	360
	7 days	-	197	220	420
	28 days	296	282	330	520
2.	Setting time mts. (vicat)				
	Initial, min	45	45	30	110
	Final, max	600	375	600	160
3.	Fineness cm2/gm	2250	2800	2250	3200
4.	Soundness				
	Le chatelier, mm (max)	10	-	10	0.5
	Auto clave % (max)	-	0.8	0.08	0.009

Table 4. Operating parameters during Finish Grinding

S No	Item	Parameter
1.	Production rate	65-75 TPH
2.	Material composition	95% clinker 5% Gypsum
3.	Fineness of product	3200-3500 cm2/gm
4.	Specific power Consumption, kWh/t	
	-Roller press, Disagglomerator & Separator	26.99
	- Other accessories	3.28
	Total system	30.27
5.	Specific power consumption, Kwh/t Conventional tube mill	38.0

Figure - 1

COMPARISON BETWEEN DIFFERENT COMMINUTION THEORIES

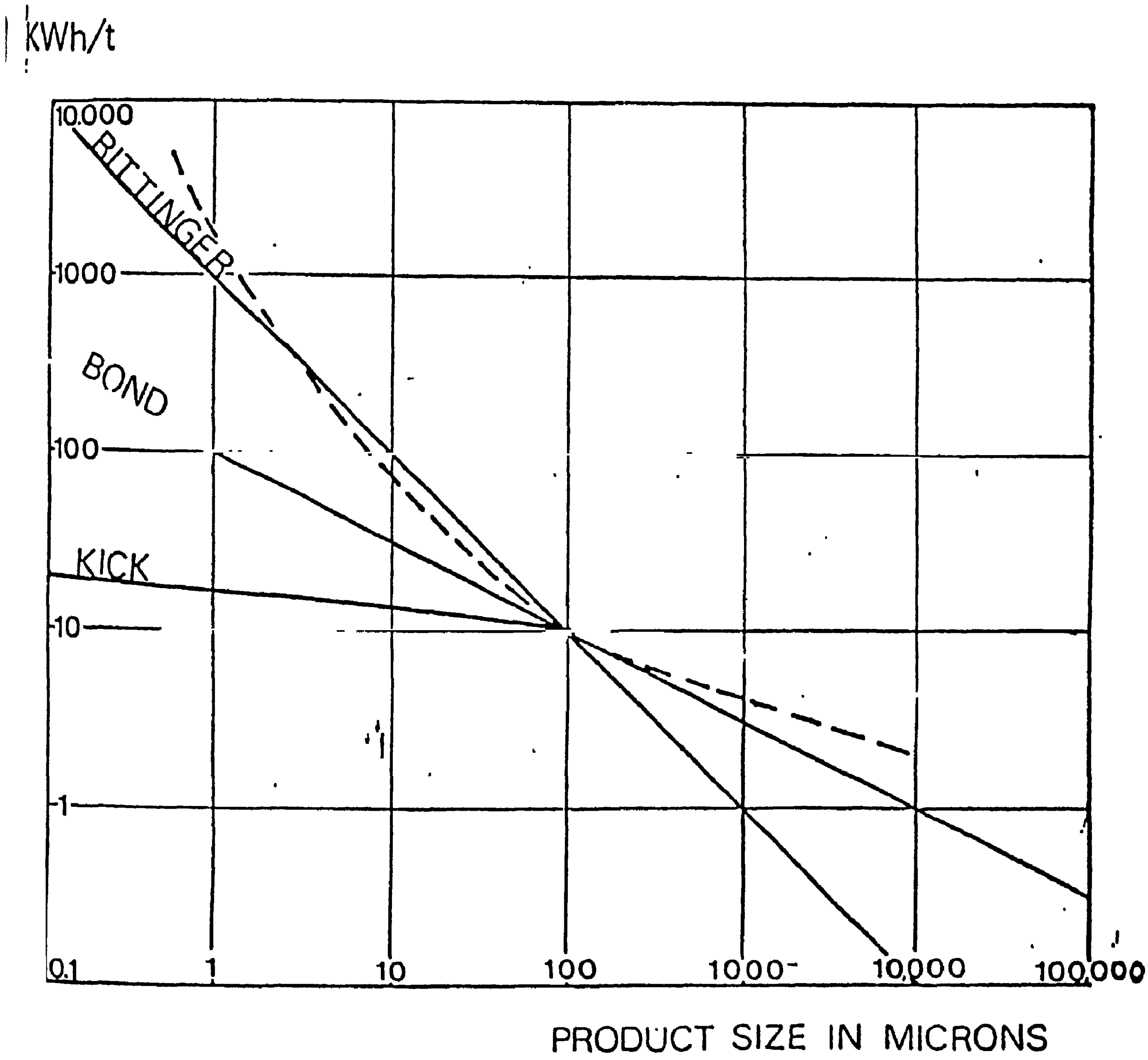
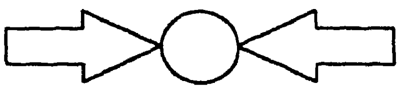


Figure - 2

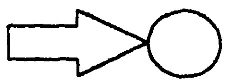
CONCEPTS OF CRUSHING, TYPES OF CRUSHERS AND RATIOS OF REDUCTION

MAJOR FORCE

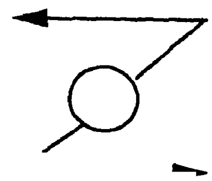
COMPRESSION



IMPACT



SHEAR



JAW

- 3-15 : 1

CONE

- 3-5 : 1

GYRATORY

- 4-10 : 1

HAMMER

- 10-100:1

BLOW BAR IMPACTOR

- 10-100 : 1

ROLLER

- 3-15 : 1

Figure - 3

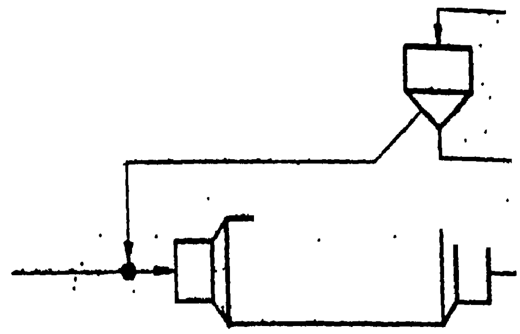
GUIDE FOR CRUSHER TYPE SELECTION

	CRUSHER FEED		
	COMPRESSIVE STRENGTH	ABRASIVENESS	STICKYNESS
JAW CRUSHER	10	10	3
GYRATORY CRUSHER	10	10	2
CONE CRUSHER	10	10	1
HAMMER CRUSHER SINGLE ROTOR	7	3	5
HAMMER CRUSHER DOUBLE ROTOR	5	3	5
HAMMER CRUSHER NO OUTLET GRATE	8	4	6
BLOW BAR IMPACTOR	8	5	6
HAMMER MILL DRYER	4	4	10
ROLLER CRUSHER SMOOTH OR BOSSED	7	8	9
ROLLER CRUSHER TEETHED	2	2	10

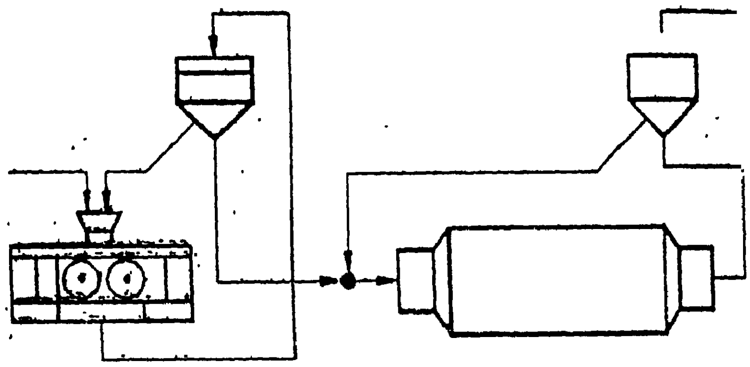
THE RANKING IS A REALTIVE SCALE 1-10, WHERE 10 IS MOST SUITABLE

GRINDING– AVAILABLE EQUIPME

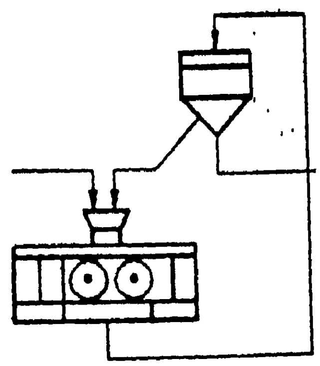
TUBE MILL



COMBINATION OF
TUBE MILL AND
PREGRINDING UNIT



ROLLER PRESS
FINISH GRINDING MODE



VERTICAL ROLLER MILL

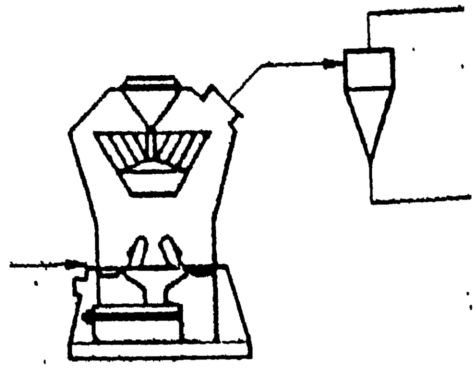
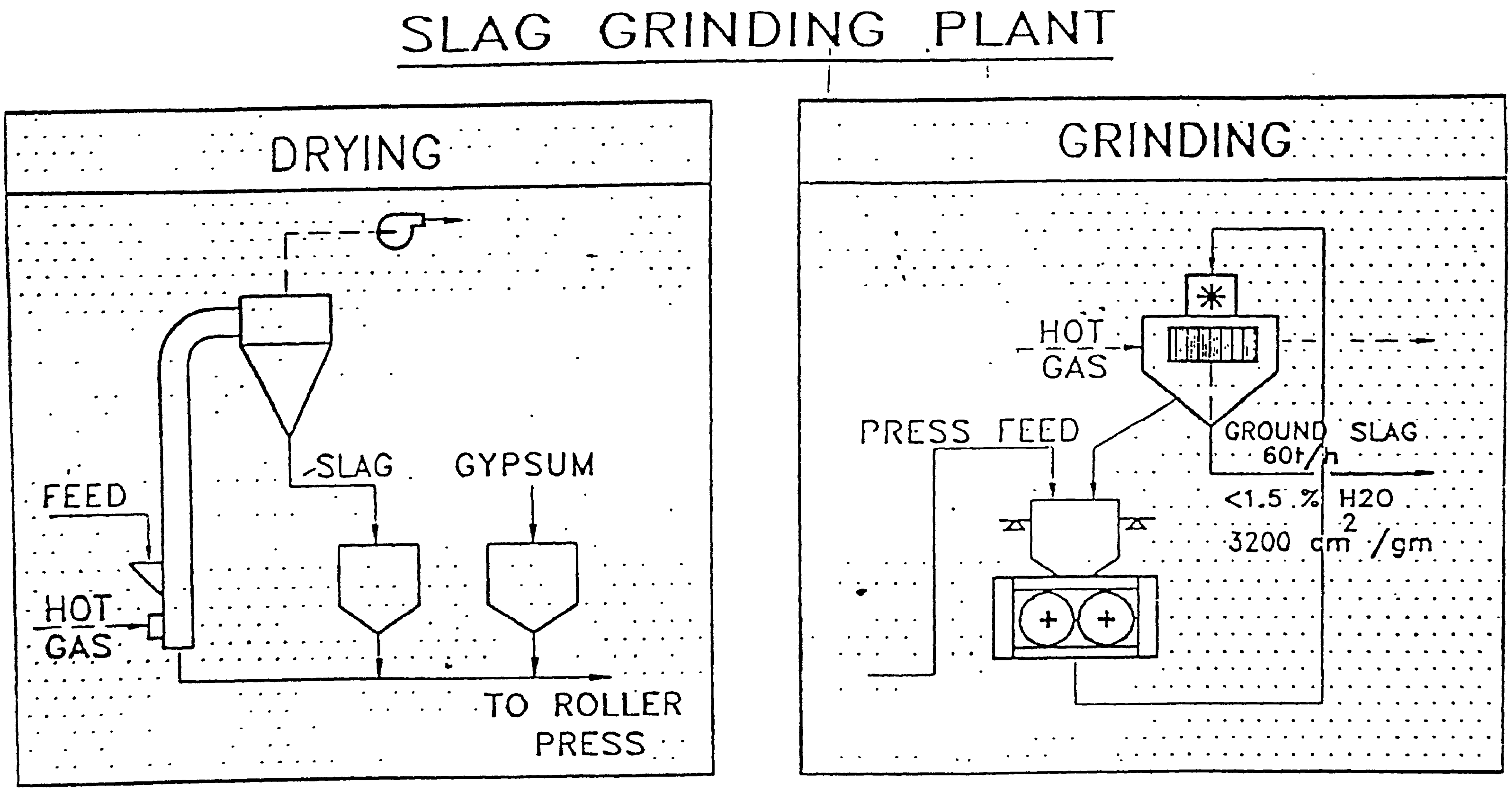


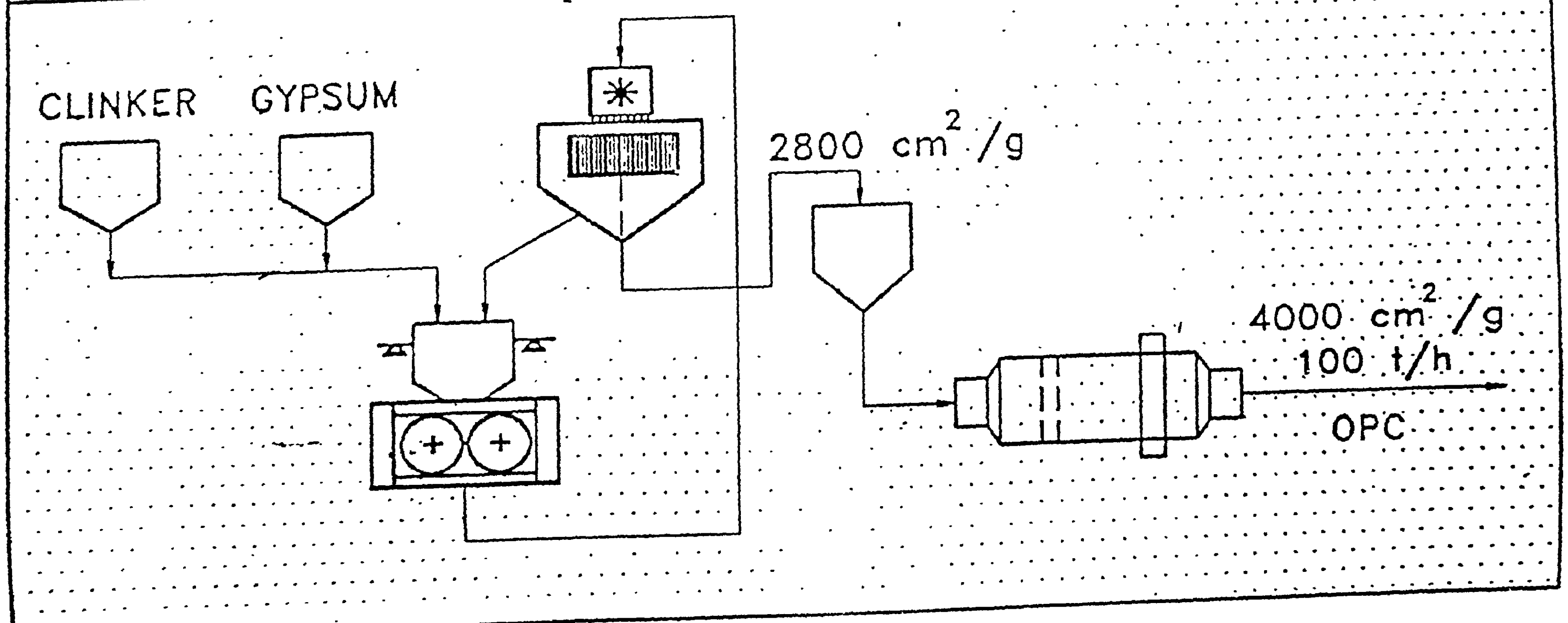
Figure - 5



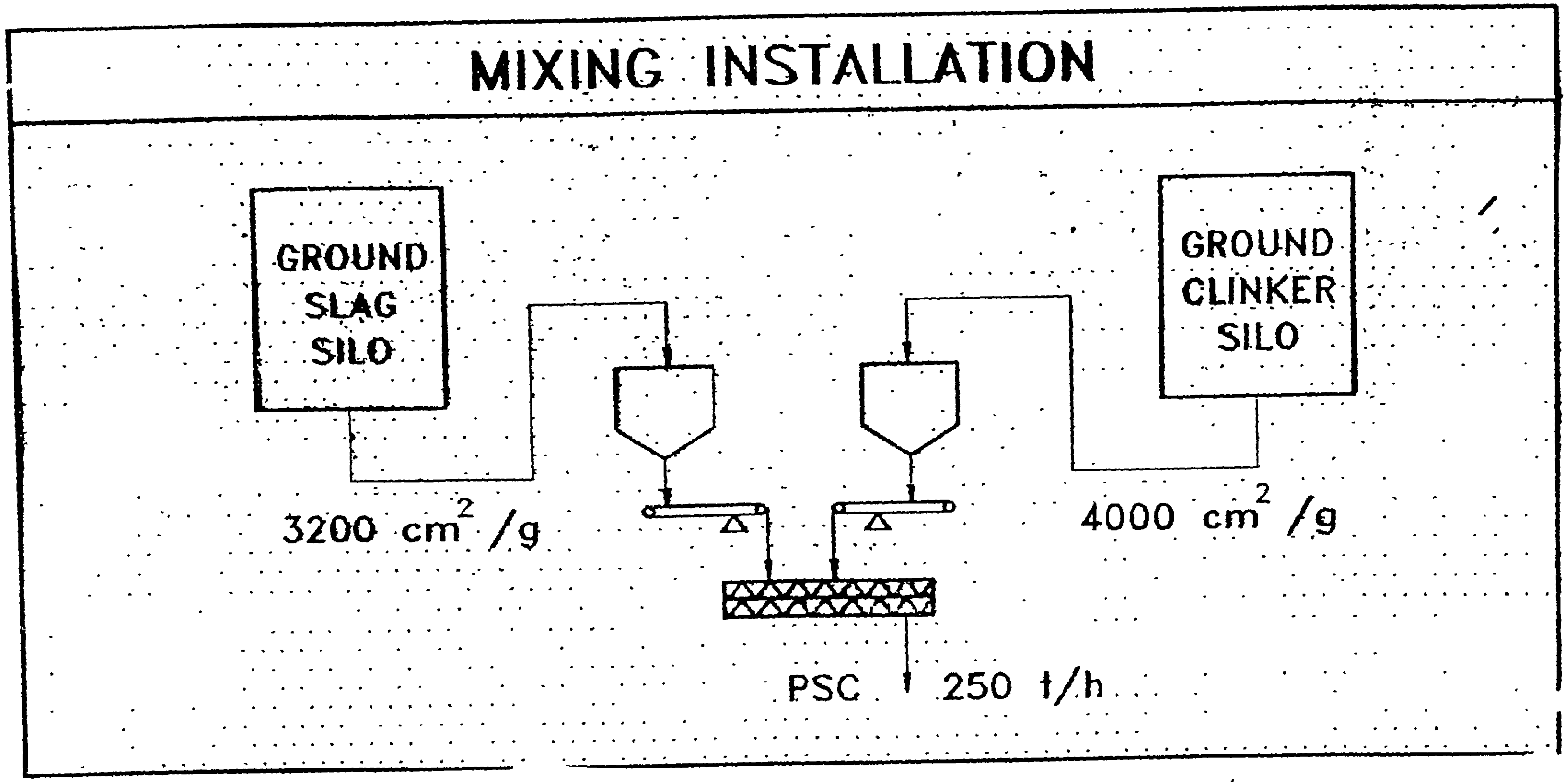
SLAG GRINDING PLANT
DRYING
FEED
HOT GAS
SLAG
GYPSUM
TO ROLLER PRESS
GRINDING
HOT GAS
PRESS FEED
GROUND SLAG
60t/h
<1.5 % H2O
3200 cm2 /gm

CLINKER GRINDING PLANT

2 – STAGE GRINDING SYSTEM



CEMENT MIXING PLANT



Energy Conservation in Pyroprocessing System

J P Mittal
NCBM

ENERGY CONSERVATION IN PYROPROCESSING SYSTEM IN CEMENT INDUSTRY

BY

J.P. MITTAL

National Council for Cement & Building Materials.

1.o INTRODUCTION

Energy consrvation is among the principal concerns of industry including cement industry through out the world and the energy crises has created a great awakening all over the world to find alternate sources of energy as well as to economise its generation and use. In view ot the chemical reactions involved which take place at very high temperature, in the range of 1400-1500^{0}C as well as physical operations involved in the process of cement manufacture like fine grinding of raw materials and fuel to ease the reactions in pyroprocessing operations and fine grinding of cement to obtain desired strength characterstics, both thermal and electrical energy forms a critical inputs to the production.

Cement production in India has a long history, starting with a modest beginning with plants of 100 tpd capacity in 1914 and upto early seventies, the cement production was mainly by wet process and the capacities were essentially below 1000 tpd; the recent trend is to have one million tonne or more capacity cement plants with dry process which are more energy effcient- particularly thermal and more economical Fig.1 show a profile of change in technology in the Indian cement industry.

The energy studies carried out by NCB reveal that the specific energy consumption in most of Indian cement plants is about 10-30 perecent higher as compared to relatively advanced countries. However, the conditions in India are different than technologically advanced countries where qualities of inputs available to cement plants are much superior. The Indian cement industry has been receiving poor quality inputs, such as low grade coal and unsatisfactory supply of power. The process wise energy consumption as shown below in table No.1 very to a considerable extent therefore the energy conservation measures will be quite different for different units and it would need specific studies for individual units for finding solutions.

TABLE -1.

Process Wise Energy Consumption

S.No.	Process	Energy consumption KCals/Kg Clinker
1.	Long Wet	1300 -1500
2.	Long Dry	1100-1200
3.	Lepol Semi Dry	950 - 1050
4.	Lepol Semi Dry (Double Pass)	800 - 900
5.	Dry process suspension preheater	800 - 900
6.	Dry process, S.P. and Precalcinator	680 - 800

2.0 IDENTIFICATION OF POTENTIALS FOR ENERGY SAVING

With a view to study the existing practices of energy utilization and for identification of opportunities for savings and improvements, extensive energy audit studies have-been carried out by NCB. These studies have shown that apart from lower capacity utilization and poor quality of energy inputs, main reasons for high energy consumption in cement plants are :

- • False air infiltration in kiln, preheater, ESP and Raw Mill Circuits.
- • Idle running of equipment, especially auxiliaries.
- • High exit gas temperatures for kiln/preheater and cooler exhaust
- • High clinker discharge temperature from coolers
- • Over sized motors/partial loading of equipment/motors
- • Improper raw meal quality and control over homogenity
- • Improper control on feed rate.
- • Poor maintenance and house keeping
- • High radiation losses from kilns preheater and cooler.

3.0 OPTIONS FOR ENERGY CONSERVATION

The major consumption of thermal energy is for clinkerisation, though small amounts are also used for drying of raw materials and coal. The various aspects which can lead to reduction in both thermal and electrical energy can be classified under the following categories:

- • Operational improvements
- • Utilisation of energy efficient equipment
- • Technological upgradations
- • Waste heat recovery

3.1 Operational Improvements

Implementation of operational improvements may involve marginal investments with almost immediate pay back benefits. These operational improvements could be classified into following categories :

3.1.1 PROCESS OPTIMISATION ASPECTS

Process parameters affecting energy consumption are discussed below.

(i) Raw Mix Design including Matching of Raw Meal and Fuel Characteristics.

Designing a raw mix after giving due weightage to the quality of the available fuel in terms of its ash content, composition and calorific value would greatly contribute to stable kiln operation and thereby to fuel economy. For example, a high lime mix and a poor quality coal will give rise to operational and clinker quality problems.

(ii) Proportioning of raw mix.

Proper proportioning of the constituents of the designed mix, adequate facilities for addition of corrective materials and strict supervision over the porportioning operations would ensure the quality of the mix. Any inconsistency in the quality of the mix would lead to fluctuations in the kiln operation thereby adversely affecting fuel consupmtion.

(iii) Crushing and Grinding of Raw Materials.

Maintenance of optimum residues of raw mix helps in smooth operation of kiln. This is facilitated by proper crusher operation with a view of ensuring that the crushed products suit the mills. The optimum residues to be maintained vary from plant to plant and is a function of the characteristies of raw materials used.

(iv) Blending and Homogenisation

Inadequate quantity of air and/or inadeqate pressure will not give the desired effect. Needles to say that properly blended mix helps in smooth burning and contributes as to fuel economy.

(v) Quality of Coal

This is very important to aviod fluctuations in the ash content and calorific value of the fuel feed to the kiln. This can be done in the coal gantry with the help of a crane/stacker using the Chevran method.

(vi) Coal Grinding and Firing System

Coal grinding systems not equipped with dust collectors for vent air, loose considerable energy in the vent air. On the other hand, improper regulation of primary air to kiln results in higher fuel consumption. For instance, every 1% excess primary air over the optimum necessitates extra fuel consumption of about 2.24 Kg/t of clinker.

(vii) Raw Meal Feed Rate

Wherever raw meal feed rate and kiln speed are not synchronised faulty operational procedures are likely to either increase or decrease the depth of material in the kiln from time to time leading to undulations in the bed. This not only impairs the heat transfer in the kiln but also adversely affects the fuel economy.

(viii) Fuel Feed Rate

In manually controlled kilns any error in computing the quantum of fuel required for a given raw meal feed rate or for restoring the buring zone temperature to the desired level will invariable lead to a hot and cold cycle which severely affects the fuel consmption.

(ix) Primary Air Proportion and its Flow Rate and Temperature.

The present trend in the cement industry is to use the least possible quantity of primary air as its own temperature cannot exceed 80^{0}C. At the same time with conventional burner the primary air quantity shall be adequate enough to carry the pulverized coal into the kiln. However, unless this proportion is optimised with respect to the firing system and the clinker cooling system fuel consumption will be badly affected

(x) Secondary Air Proportion and Temperature

As the function of secondary air is to recover the heat from the hot clinker discharged from the kiln its quantity shall be adequate enough to achieve highest possible thermal efficiency. In other words, the secondary air temperature shall be as high as possible. In the case of grate coolers balancing of the air flow into the kiln and the cooler exhaust plays a vital role in efficient burning and contributes to fuel saving if properly exectued.

(xi) Kiln Speed
Changes in kiln speed are caused by the a) to keep the buring zone temperature constant b) the urge to achieve maximum possible production rate. In the absence of a suitable device for measuring the burning temperature operator's error in estimating the temperature more often leads to overburing and extra fuel consumption.

(xii) Burning Zone Temperature

The burning zone temperature is a very important parameter as it affects total clinkerisation process, the quality of clinker produced as well as fuel consumption in cement manufacturing. The burning techniques in use all over the world rely on either the burning zone temperaturtre or the back end temperature being kept constant during the kiln operation. In the former technique kiln speed and fuel feed rate are the varibales used for maintaining the burning zone temperature constant. If appropriate judgement is not exercised by the kiln operator fuel consupmtion is likely to increase.

(xiii) Raw Meal Burnability

Fluctuations in burnability of raw meal will increase the fuel consumption.

(xiv) Pulverized Coal Finenss and Moisture Content

Coarsely ground fuel (coal) does not burn completely in the burning zone with the conventional burners necessitating higher fuel input to maintain the burning zone temperature at the required level. Apart from higher fuel consumption kiln operation will not be smooth.
Similarly, higher residual moisture content in kiln feed coal results in extra fuel consmption. For instance every 1% extra moisture requires 0.35% Kg of coal for 1000 kg of clinker additionally. Power consumption of the ID fan also increases.

(xv) Excess Air

Either less, or more than the optimum quantity of excess air leads to extra fuel consumption. While less air results in incomplete fuel combustion more air necessitates extra fuel consumption. In both the cases, fuel economy is affected. For instance 1% extra air consumes 0.2% extra coal. In addition ID fan power consumption also increases.

(xvi) False Air

Infiltration of air into the kiln system from any point results in extra fuel consumption as well as additional load on the ID fan. The extra fuel required depends on the number of infiltration points and their location in the kiln system as well as the extent of leakage at each point.

(xvii) Back End Temperature and Draft

Maintenance of optimum back end temperature and draft contributes to fuel economy. Deviations from optimum values result in additional fuel and power consumption.

(xviii) Hood Pressure

Control of hood pressure is important with all coolers. But it is more critical in grate cooler kilns on account of additional air used for after cooling of clinker. Imperfect control in mannually controlled operation disturbs the air balance and may give rise to extra fuel consumption.

(xix) Dust Concentration in Combustion Air

Poor granulometry of clinker and/or dusty clinker leads to abnormal concentration of dust in the combustion air which impairs the combustion process thereby adversely affecting the fuel consumption

(xx) Kiln Torque and No x Meter

Correct interpretation of the values given by these meters helps in reducing fuel consumption.

(xxi) Clinker Cooler Officiency

• Thermal Efficiency
Maintenance of optimum undergrate pressure for obtaining maximum possible secondary air temperature is a prerequiste for attaining highest thermal efficiency. Poor/enefficient recovery of heat results in extra fuel consumption.

• Air used for after Cooling
Optimum quantities only should be used Excess air puts an additional load on the cooling fans and the cooler exhaust fan

3.1.2. ELECTRICAL AND INSTRUMENTATION ASPECTS

- Idle running of equipment in a plant causes a lot of wastage of electricity which could be avoided with proper attention in this direction.

- Use of sequence interlocking mechanism such as PLC (Programmable Logic Controller) will not only reduce idle running of machines but will also improve ease of process control.

- Power factor improvement could be achieved through the application of capacitor banks and synchronous induction motors.

- Better load management efforts

- Avoiding frequent start/stops of motors.

3.1.3. **MAINTENANCE AND HOUSEKEEPING**

- Better preventive maintenance and use of moden condition monitoring techniques, e.g evaluation of kiln ovality and alignement, bearing analysis,V-belt tension measurement, vibration monitoring, thermography etc. goes long way in reducing downtime and increasing capacity utilisation.

- Improved housekeeping helps reduction of energy consumption.

3.2 Installation of Energy Efficient Equipment

Energy audit studies provide an opportunity to examine the performance of the available equipment. In some of the plants, NCB's studies showed the need for replacement of the old rheostate type speed control system of the variable speed motors by new slip recovery system.

During rationalisation of operations or expansion programme of the plants, it is advisable to take advantage of the latest technology and energy efficient equipment. The new energy effiecient equipment/system may be high Pressure Grinding Rolls, Vertical Roller Mills, High Efficiency Fans, Slip Recovery Systems, Waste Heat Recovery systems, Computerised Controls, Efficient Combustion System, Improved Classifiers, Variable Speed Drives, Fluid Couplings, Soft Starters etc.

3.3 Technological Upgradations

Development in kiln technology aimed at improving performance of existing cement plants and come out with new energy efficient equipment and systems, are discussed as below :-

3.3.1. **PROCESS CONVERSION**

Though the process of conversion from wet to dry process is capital intensive, it is to be noted that every 1% of moisture content in the raw meal charged to the kiln needs 15-18 kcal/kg clinker.

3.3.2 **FIVE/SIX STAGES PREHEATERS**

Recent development in improved cyclone designs have led to the concept of five/six stage suspension preheaters in place of conventional 4 stage preheaters. The exit gas temperature gets reduced by about 40-50 ^{0} C with the resultant thermal energy saving of 25-40 kcal/kg clinker without adversely affecting the power consumption.

3.3.3 LOW PRESSURE CYCLONES.

The prehater system equipped with low pressure cyclons are designed to reduces pressure drop in the preheater system. These designs aims to optimise the performance of conventional cyclone systems which include modifications of the cyclone inlet-duct cross-section, angle of entry, installation of guide plate at inlet and altering the shape of the immersion tube. These modifications have resulted in substantial reduction in pressure drop of 20-25% and also reduction in size of cyclones.

3.3.4 MULTI CHANNEL BURNERS

One development of considerable importance in the Indian context is the multichannel burner which improved the kinetics of combustion and helped in using high ash coal. The three channel buner with axial air, swirling air and the coal injection channels is now in use in many Indian cement plants.

3.3.5. THE FLS-FULLER CONTROLLED FLOW GRATE SYSTEM

The most significant advancement in technology for grate coolers over the past decade is the introduction of controlled flow grate (CFG) concept to allow complete control over the flow of air and material through the cooler.

Cooling air is supplied directly to the grate plates, essentially eliminating the under grate compartments. Each row of grates mounted on an individual air beam which is devided into a number of chambers across the width of the row. These chambers are supplied with cooling air from several cooling fans with piezometer control from a system of manifolds located outside the walls of the cooler and piping in the under grate chamber. By supplying the cooling air in this manner, it is not lost through leakage and it is possible to assure that cooling air is passing through all the material on the grates.

By controlling the flow of material and air through the cooler, theremodynamic and mechnical efficiency are dramatically improved. Of primary interest are the increase in combustion air temperatures and resultant fuel savings besides more stable operation and reduced cooler maintenance.

3.3.6. PENDULUM COOLERS WITH HORIZONTAL AERATION OF CLINKER :

Fast clinker cooling with excellent recuperation can be achieved by introducting strong horizontal air jets in the clinker bed. The advantage of horizontal aeration is no turmoiling of the clinker bed, no sand blasting effects on the grate plates, soft transport of fines to the bed's surface and a sharp temperature profie acrose the clinker bed. IKN develeped the COANDA nozzle, named after Romanian Mr, Coanda, which generats strong air jets adzacent to grate surface and prevents the passage of clinker through grates and are part of IKN fixed clinker inlet distribution system. The first six to eight existing rows were replaced by stationary and enclosed air beams aerated by individual ducts. The IKN cooler design provides a self centering pendulum suspension of mobile frame. Moving parts such as rollers, bearing and sliding seals are eliminated and the fixed arrangement resulted in much less wear and a noticable improvement of heat recuperation and inturn thermal efficiency.

3.4. Waste Heat Recover By Cogeneration

Another important area requiring attenion is waste-heat utilisation to generate power, particularly in case of relatively large size cement plants. NCB's studies indicate that in dry process plants nearly 40% of total heat input is rejected as waste heat from preheater and cooler. The quantity of heat lost from preheater ranges from 180 to 250 Kcal/kg clinker at 300-400°C and from cooler the amount of heat lost is 80-130 kcal/kg cliner at 150-300°C. Studies have indicated that upto 30% of the total power requirement can be met through co-generation.

4.0 ENERGY AUDIT - THE VEHICLE FOR ENERGY CONSERVATION

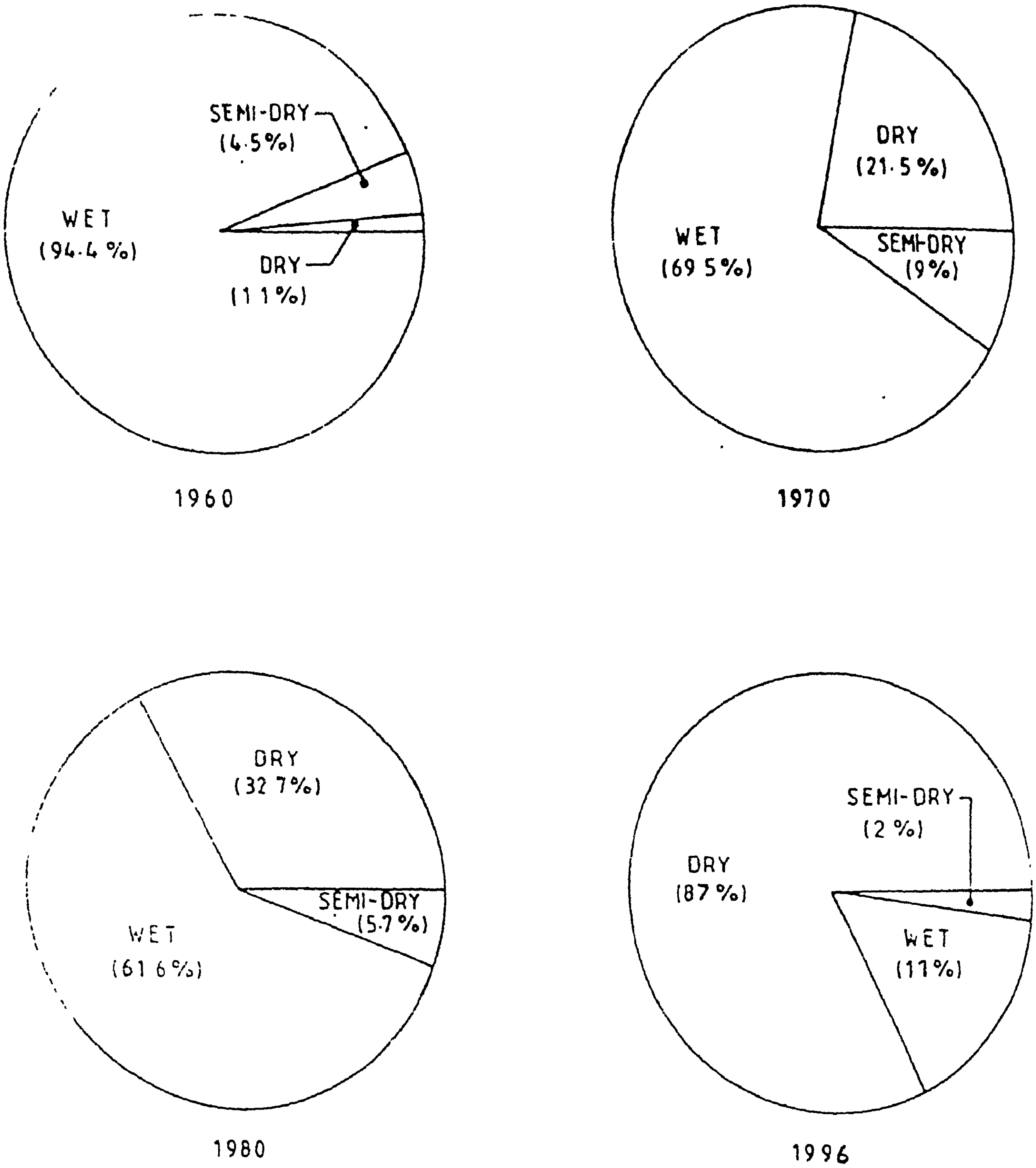
Energy audit provides all the vital information for overall energy management programme. Energy Audit makes a thorough search for the areas of energy wastages and tries to identify the reasons for these wastages. It provides an immense wealth of information to the various levels of operation in a plant to carry out the task of energy conservation in effiecient manner.

4.1 Energy audit is essential tool for :

- Examining the level of energy consumption
- Creating information base
- Identifying energy conservation potentials
- Plant to plant comparison with past performance for assisting in the development of guidelines, policies and programmes for energy conservation.
- Identification of need for manpower development
- Identification of project proposals for energy saving.

5.0 CONCLUSION

The rising costs of both electrical and thermal energy inputs and its resultant effect on the economics of production of cement calls for closer attention to be given in the area of energy conservation. For maximising the efficiency of cement plants, an intergrated energy management aproach would be necessary to realise maximum possible energy saving in the manufacture of cement.



CHANGING PROCESS PROFILE OF INDIAN CEMENT INDUSTRY
THE SHARE OF INSTALLED CAPACITY OF CEMENT THROUGH DIFFERENT PROCESSES

FIG 1

Environment Regulations and Monitoring in Cement Industry

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Environment Regulations and Monitoring in Cement Industry

1.0 Introduction

With the rapid growth in the industrial activities, the impact on environment is increasing rapidly. Pollution is a worldwide phenomena and has inherently been existing along with rapid industrialization in the developed as well as developing countries like India. There is a wide-spread realization and awareness in respect of environment protection and pollution control from industries such as Cement and Mining. A need is being felt for appropriate actions to prevent further environmental degradation for improving the 'Quality of Life'.

As it is evident, any developmental activity should be combined with good environmental protection measures. Cement production is essential for industrial, energy, irrigation & housing sectors, which improve quality of life. Control of environmental degradation is equally essential to improve quality of life. So both these activities are to be balanced. This balancing act is to be performed by engineers, scientists and environmentalists to maintain a dynamic equilibrium on the earth.

Cement Industry ha been identified as one of the highly polluting industry by the Ministry of Environment and Forests, Govt. of India and also by Central Pollution Control Board. The particulate matter, in the form of stack emissions and fugitive dust, are the major sources of air pollution affecting the environment within a radius of 10 kms around the cement plant. A research study states that kiln stack alone contributes to about 92% of total emission from a cement plant.

The Indian Cement Industry has shown spectacular growth in the last 50 years. Way back in 1947, the installed capacity was just 2.22 million tonnes per annum which now is over 100.00 million tonnes per annum. There are 129 clinkerisation and cement grinding plants in India. The clinkerisation units number 190, out of which 121 units are operating on dry-process technology and the rest on semi-dry and wet process technology. About 96.0% of clinker production comes from the dry process plants. Capacity and technology wise classification of clinkerisation units is as under:

S.No.			Installed Cap.	No. of % production Units
1.	<600 Wet	61	2.0	
2.	600-1500	Dry	24	8.0
3.	1500-3000	Dry	47	34.0
4.	>3000 Dry	58	56.0	
		190	100.0	

2.0 Regulations

Ministry of Environment & Forests (GOI) and Central Pollution Control Board (CPCB) are the regulatory authorities. Comprehensive legislations are in force such as:

- Water (Prevention and Control of Pollution) Act 1974.
- The water (Prevention and Control of Pollution) Cess Act, 1977.
- The Air (Prevention and Control of Pollution) Act 1981.
- The Environment Protection Act 1986. It came into force in whole of India on 19 November, 1986.
- Govt. of India was getting increasingly concerned about pollution in coastal region and set-out special regulations concerning industrial activity in coastal regions. Coastal Regulation Zone was notified on 19th February, 1991 restricting industrial and other activities within 500 meter from the high tide line of the coast.

The Air (Prevention and Control of Pollution) Act, 1981, and the Environment (Protections) Act, 1986 have together put responsibilities and authority with Central Pollution Control Board and the State Pollution Control Boards. The CPCB has fixed standards for ambient air quality in respect of suspended particulate matter (SPM), Sulphur-di-oxide (SO2), Carbon Monoxide(CO) and Nitrous Oxides (NOx). The standards are:

Ambient Air Quality Standards

No.	Area Category	SPM	SO2	CO	NOx
		μg/m3	μg/m3	μg/m3	μg/m3
1.	Industrial & Mixed	500	120	500	120
2.	Residential & Rural	200	80	200	80
3.	Sensitive	100	30	100	30

Emission Limits from Stack

Plant Capacity TPD		Particulate matter Emissions not to exceed mg/Nm3	
		Protected Area	Other Area
a.	< 200	250	400
b.	> 200	150 115 (in AP)	250

3.0 Monitoring of Pollutants

Air Pollution in cement plants mostly deal with particulate matter (SPM) from stacks and fugitive sources arising from material handling. Gaseous pollution is minimal due to raw-material & fuel characteristics. The cement dust generation is caused due to the fine powder handled in each section of the cement plant ranging from crushing section to the packing section. The fine dust from the dry pulverised raw-materials. such as limestone, coal, gypsum, laterite, clay & shale as well as semi-finished and finished products like clinker & cement, remain air-borne. Some percentage of fine dry dust can not be arrested by pollution control equipments like ESP, Bag-House etc. These dust particles are emitted to the atmosphere through tall chimneys (stacks), so that the fine dust disperses into atmosphere. Depending on meteorological parameters, emitted dust is carried to far-off places by the wind.

Monitoring of environmental parameters is carried-out during pre-project period_Rapid EIA study for one season, and also after commissioning of the Cement Plant_comprehensive EIA study for four seasons of the year. For a new green-field/expansion/modernisation of cement project, conducting an EIA/EMP study is a pre-requisite, towards obtaining statutory clearance from State Pollution Control Board and Ministry of Environment & Forests, (GOI).

In the selection of site for cement project, factors such as topography, geology, hydrology meteorology, raw-materials and fuel storage & handling etc. are considered. Ecologically sensitive areas like national parks, wild life sanctuaries, tropical forests, bio-sphere reserves, lakes, hill resorts, historical and archeological monument, seismic zones, defence installations, air-ports, border zones, major settlements are to be sited 25 kms away. The coastal areas, flood plains of riverine highways, railways shall be 500 meters away. No forest and prime agricultural land is to be utilized. The project site should remain obscured from general site and area must confirm to the landscape.

For a rapid EIA study following is a schedule of monitoring:

- Ambient air quality with respect to SPM, RSPM, SO2, NOx and CO for one season. A season (other than rainy season), comprising of three months atleast two days per week for thirteen weeks. The sampling is to be done 8 hourly round the clock per day.
- Measurements of meteorological parameters such as wind velocity and direction relative humidity, temperature, cloud cover and rainfall for 13 weeks of the season.
- Identification and quantification of stack emissions from different sections of the proposed plant. Measurement of stack emissions from the existing cement plant in case of expansion or modernisation project.
- Water/effluent sampling and analysis as per IS-2490 and IS-10,500.

- Measurement of ambient noise levels and sources of noise generation.
- Hydro-geological studies for availability of water_quality & quantity, ground water profile etc.
- Computerised air dispersion modelling for predicting SPM and gaseous levels.
- Data on current land-use, cropping patterns, flora and fauna, demographic and socio-economic profile etc.
- Identification of sites where land is un-occupied/sparsely populated to enable minimum human displacement.
- Estimation of likely stress (heat, dust, noise) on workers in different sections of the plant.
- Data collection for transportation and handling of raw-materials.
- Specific emphasis on sensitive targets within 10 kms. radius.
- Data of pollution control equipment and environment protection measures.
- Site map, lay-out plan.
- Material & water balance diagram.
- Socio-economic study for area within 10 kms. radius.

Pollution Abatement Measures and Technologies in Cement Industry

A Vajpeyi
ACC, Thane

Pollution Abatement Measures and Technologies in Cement Industry

As you all are already aware the manufacture of cement is a four step process involving

Acquisition of raw material
Preparation of raw materials for pyroprocessing
Pyroprocessing to produce clinker
Grinding of clinker to form cement

During the above processes a cement plant contributes to generation of suspended particulate matter and gaseous pollution. Emission of particulate matter is largely contributed by the stack and fugitive sources. The fugitive dust generated from various sources affect the safety and performance of workers, cause wear and tear of equipment and thus adversely affect the life of men & machinery The stack emission on the other hand is dispersed over a much larger area and thus has an adverse impact on the environment and health of the people living in the area surrounding the plant. Gaseous emissions from stack comprise mainly of CO_2, NO_X and SO_2. However, Cement manufacture doesn't generate any liquid effluent or hazardous waste.

Emission Norms
The emission limit for a large Cement Plant in a protected area is 150 mg/Nm^3 as per the CPCB norms However, the SPCB emission norms would be lesser or equal to the CPCB emission norms

Particulate Emission Control
Suspended Particulate matter is emitted in a cement plant from the following areas apart from the fugitive emission

Mills.
Kiln
Cooler
Crushers, Silos and Packing House.

The following equipment are in vogue today for the control of particulate matter above mentioned applications

Electrostatic Precipitator
Reverse Air Bag House
Pulse Jet Bag Filter

Electrostatic Precipitator
ESPs are being used in the Raw Mill, Coal mill, Kiln, Slag Dryers, Captive power plants, DG sets and Coal based Power Plants, Cooler and Cement Mill applications. However, of late the use of ESPs is being limited to combined mode operation for Raw Mill - Kiln and Clinker Cooler application.

Raw Mill - Kiln Application
The combined mode of operation comprises of twin gas path whereby hot kiln gases are sent through Raw Mill and Gas Conditioning Tower parallel before being fed to the ESP for cleaning. The dust collected within the ESP hoppers is then recycled and fed to the Blending Silo or the Kiln feed system thereby achieving a closed loop system. At times it is difficult to recycle the ESP dust due to variations in Chemical Composition and granulability of the dust.

Clinker Cooler Application

ESP for a clinker cooler is a very tricky piece of equipment to be designed. Clinker Cooler Vent Fans usually operate at reduced vent volumes for most of its life cycle. However, at times i.e. during upset conditions the cooler vent volumes and temperature increase drastically. It has been seen that the clinker cooler may have a water spray system in the clinker bed. Also in some cases duct cooling is provided up stream of the ESP to improve its performance. Thus a clinker cooler ESP sees a variation in volume, temperature and moisture over a large range.

We would like to stress that this ESP should be sized and designed to work under most adverse conditions of high volume, temperature and zero moisture. Any compromise on this would lead to a non performing ESP, when it is most required.

ESP Latest Design Trends

The following design trends are being incorporated in the ESP for long life, high reliability and constant performance.

Points to consider while selecting an Electrostatic Precipitator

- Total ESP Collection Area.
- Gas passage width.
- Total treatment length.
- Total treatment time across all fields.
- Number of Electrical fields.
- Number of Mechanical fields.
- Number of TR sets and its rating.
- Gas velocity.
- ESP aspect ratio.
- ESP inlet and outlet cone configuration alongwith type and number of gas distribution devices.
- Guaranteed Outlet Emission.
- Guaranteed Outlet Emission with one field out.
- Type of Collecting & Discharge Electrodes. Type and number of Rappers.
- Type and configuration of hopper
- Maintainability of ESP components during operation,
- Reliability and life of ESP components. Cost of operation.
- Cost of spares over a period of time.
- Possible shutdown on failure of components.

Rigid Discharge Electrode

These type of electrodes are being used in ESPs by all the major European and American manufacturers today as their life and performance is unparalleled in the industry. This trend is yet to become the industry standard in India.

Seal Air System and Penthouse Design

All American ESP manufacturers provide a penthouse for safe-and reliable operation of the HT system. These penthouses are equipped with a seal air system with heaters to get rid of individual Insulator Heaters and maintain clean support Insulators. A penthouse with a seal air system achieves greater reliability, energy efficiency and on-line maintainability.

HT Field Split

The discharge electrodes in one ESP field is further subdivided into two or more number of bus sections. Thus one mechanical field of an ESP may comprise of two or more number of electrical fields thereby offering greater electrical sectionalization. This feature marginally improves the overall separation efficiency of the ESP. Unfortunately however, this feature can be applied only to the American Design ESPs and not to European design due to differences in the basic design philosophy.

Reverse Air Bag House (RABH)

There has been a recent trend of using Reverse Air Bag House for Raw-Mill / Kiln application. This has been propelled by the imposition of strict statutory pollution norms and also due to changes in process conditions. Woven Fibreglass bags with Graphite, Silicone and Teflon and reverse air coated treatments are being used for this application. Bag House for kiln application The is usually designed for an operating temperature of 220 - 250^{0}C. This temperature is strictly to be maintained by use of air dilution or heat exchanger system. Any temperature excursions would lead to damage / reduction in bag life.

To prevent damage of filter bags due to failure of first line of defence i.e. temperature control, a backup Bag House Bypass system, is also a viable solution.

Point to consider while selecting a Reverse Air Bag House

- Total Filtration Area (Gross, Net, Net-Net).
- Air to cloth ratio (Gross, Net, Net-Net).
- changes in process conditions.
- Size, Quantity, make, weight and finish of bags.
- Number and configuration of modules.
- Type and size of inlet, outlet and reverse air duct
- Normal and maximum system pressure drop
- Type, size and Quantity of Reverse Air Fan. Type, size, location and quantity of Bypass Reverse Air
- Location and response time of temperature control system
- Dust Evacuation System.
- Type and location of stairway, access system, maintenance system

Bags

The bags should be of fibreglass fabric coated with SGT (Silicon, Graphite Teflon) treatment. Features which are important for the selection of these bags are its permeability, weight, number of antideflate rings, the distance between them. Factors which are important for its operation and longevity are proper bag tensioning, complete compartment isolation during cleaning, required quantity of reverse air at the required pressure and temperature.

Pulse Jet Bag Filters

Pulse Jet Bag Filters are used for usually used for raw mills, coal mill, cement mill and other venting applications in a cement industry. However, recently their is a trend to use them in the Raw mill and Kiln application.

The following important and critical features must be considered while designing these bag filters.

Points to consider while selecting a Pulse Jet Bag Filter

- Total Filtration Area (Gross, Net).
- Air to cloth ratio (Gross & Net).
- Type of bag access arrangement (top door/ inlet plenum).
- Fabric, Finish, make, permeability, burst strength, tensile strength, finish, size and quantity of bags.
- Size, wire size, no. of wire per cage.
- Quantity and quality of cleaning air.
- Normal & Maximum system pressure drop.
- Sizing of compressor
- Method of flow balancing through various modules

Cage

The cages act as bag support device while the bags carryout filtration. Thus any defect/ in cage, its workmanship/ or an improper cage selection ultimately results in premature failure of bags. Hence, apart from the critical nature of bag fabric and stitch the bag cage, no of wires thickness of wires material of construction (special treatment), distance between the spacer rings of bag cages for the particular type and size of bags is very important.

Special features for coal application

The coal mill bag filter are becoming more popular compared to the conventional ESP from the point of view of lower capital cost, lower emission and simplified design. Special features incorporated for such application are as follows :

Casing hopper designed to withstand a reduced explosion pressure of 1.4 bar as per VDI-3673.

Venting arrangement in ducting upstream of bag filter.

Explosion vents.

Inertization system with CO_2 or N_2 within the bag filter.

Proper filter media.

Other features

The bag to bag clearance is very important. This clearance decides the dust loading which is actually seen by the filter bags (low clearances between bags results in dust recycle because of high gas velocities in the inter-bag regions, also termed as can velocity)

Problem / Critical areas

At this juncture we would like to highlight that since pollution control equipment are considered non production equipment, very little attention is paid to its design features, components and maintenance. This ultimately ends up on a non performing equipment.

Electrostatic Precipitators

It has been observed that even though ESPs are designed for a particular application they fail to perform upto the desired mark. These problems are usually contributed by the following factors (assuming that the ESP is adequately sized)

Improper Gas Distribution

Improper / Fluctuating process conditions

Gas Distribution

ESPs are volumetric gas flow equipment and thus all parts of the ESP should have equal amount of flow during its operation. This is rarely so. It has been observed that the flow varies drastically from one X - area if an ESP to another X-area of the same ESP. This results in an overall drop in the equipment efficiency. Such an anomaly is corrected by changing configuration and size of Holes on the gas distribution plates. The tests regarding the GD plate configuration is usually performed on a lab scale model of the ESP or on a computer model.

Improper process condition

The resistivity of the dust entering the ESP varies exponentially due to change in moisture content. Ideally we should try and lower the temperature as low as 130^{0}C (except in case of kilns where lignite is also fired) at the GCT outlet by moisture conditioning However, this is rarely achieved due to the following problems in the GCT :

Inadequate GCT size.

Inadequate GCT inlet design.

Improper Gas Flow Distribution within the GCT

Incorrect nozzle / lance selection.

Incorrect nozzle orientation.

Wear and tear of nozzle tips, leads to increase in nozzle outlet hole resulting in bigger droplet size.

Water Quality.

Gas Conditioning Tower

It has been observed that today the cement plants are operating at capacities higher than their original design capacities, thereby making the GCTs inadequate to handle higher gas volumes.

The above mentioned problem of GCT are circumvented by replacing the conventional spill back nozzle system with air assisted nozzle system at lower pressure of 5-6 bar (g). Greater degree of droplet atomisation (lower particle size) is achieved in air assisted nozzles requiring lesser evaporation time and thus these used in case of undersized GCTs.

Points to consider while selecting a Gas Conditioning Tower

- GCT size (height and diameter)
- Gas velocity and residence time.
- L/D ratio
- Type of water spray system
- Quantity and size of nozzles and lances.
- Back up system (pumps and compressor). Method *of gas* distribution.
- Type of dust evacuation system.

Major Problems related to Wrong Gas Distribution, Nozzle Selection & Orientation.

Gases and water seldom flow uniformly over the cross-section of the GCT. This results in part of the gases getting more than its share of moisture, thereby resulting in the following problems :

GCT wet bottom.

Outlet temperature much higher effecting separation efficiency of downstream ESP.

Often dust lumps leads to jamming, in turn affecting plant output

Thus the ESP has to operate with a higher inlet temperature, gas volume and lower moisture level thereby drastically reducing its separation efficiency. These problems are overcome by improving the GCT gas distribution and improving the lance and nozzle configuration to achieve uniform gas distribution and lower outlet temperature without any wet bottom

To solve the problem of non-operating ESPs other solutions available are :

Addition of fields in series or in parallel.

Converting ESP to Bag Filter within the same ESP casing fully or partly.

Addition of Bag Filter in series or in parallel

Pulse Jet Bag Filters

Bag filters usually do not perform due to the following reasons

Improper gas distribution.

Compressed air pressure and quality

Quantity and required head..

Quality.

Selection of correct filter media i.e. weight, permeability.

Regular maintenance.

Pulse Cycle and duration.

Improper Gas distribution

Proper gas distribution is very important in a bag filter. This prevents part of the bags being overexposed to dust / gases. If however, improper distribution exists it forces a part of bags to be clogged early and finally culminate to excess -loading on other bags. Such a problem usually results in premature failure of bags.

Compressed air quality

The moisture and oil content of the compressed air should be as specified. Any deterioration in the quality of compressed air results in clogging of bags due to exposure of bags to moisture. Thus it is essential that the compressed air should be oil free and dry. Also, inadequate cleaning air results in bags not being cleaned resulting in higher pressure drop and deterioration in bag life.

Various bag filters are upgraded to vent a higher gas volume / dust load by changing the bags with Teflon coated (membrane) instead of installation of extra modules.

Latest Trends

A common pollution control system for the raw mill-kiln and clinker cooler circuit A common system may consist of a GCT-ESP or a Bag House. Already, there are a few installations in Europe which have a FD Cooler and a Bag House catering to the Raw mill - Kiln and the clinker cooler venting.

Use of Pulse Jet bag filter for Kiln application with membrane coating on woven fibreglass. A number of such installations have recently come up.

Fugitive Emission Control

Fine dust particulates are generated in every activity of production, i.e. right from quarrying to packing, still remains one of the most difficult to control. Fugitive emission- sets in primarily during transportation, storage, blending and handling of raw materials, intermediates and finish product.

Various systems used for fugitive emission control are as follows :

Transfer point bag filters.

Water spray systems used at various transfer points and other locations.

Covering and enclosing gantries and various conveying equipment.

Statutory norms spell out a limit of 3 mg/m^3 at a radius of 3m from the point of generation of fugitive emission. These norms are difficult to achieve and are a stiff challenge.

Gaseous Emission Control (SO_2 and NO_X)

The source of SO_2 is the sulphur and its compounds in the fuel and raw materials. Unlike other industries cement manufacture has a unique desulphurisation mechanism in the process, where lime and alkalis react with the sulphur and the same is trapped in the clinker. The process itself captures around 70-90% of the sulphur and balance appears in the stack. Further reduction in SO_2 in stack gases can be achieved by specific desulphurisation measures.

The clinker firing system causes formation of NO_X as in any other combustion system in the calcining Zone (from nitrogen in the fuel) and the sintering zone (atmospheric nitrogen). The NO_X levels could be reduced by optimised use of the kiln burner with the flame management system, catalytic, non-catalytic and use of multiple multistage combustion systems.